AIR LEAKAGE IN EXISTING TOWN HOUSES

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AIR LEAKAGE IN EXISTING TOWN HOUSES

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The views and conclusions expressed and the recommendations made in this report are entirely those of the authors and should not be construed as expressing the opinions of Alberta Municipal Affairs.

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FOREWORD

The project documented in this report received funding under the Innovative Housing Grants Program of the Alberta Department of Housing. In May, 1986 the Alberta Department of Housing was amalgamated with Alberta Municipal Affairs which is now responsible for issuing this report.

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EXECUTIVE SUMMARY

Air leakage through walls and roofs is a major contributor to space heating requirements in housing. This study of air leakage in existing town houses was undertaken to determine:

(i) air tightness of town house envelopes compared with single family dwelling envelopes,

(ii) major routes of air leakage in town house envelopes, and

(iii) the effect of construction details and workmanship on air leakage through town house envelopes.

Air tightness was measured by the depressurization method, in which a powerful fan is used to draw air out of the dwelling. The air flow rate through the fan nozzle is determined, and this provides a measure of the tightness of the envelope. This method is finding widespread use and such testing is required for certification of R2000 dwellings. In the case of town houses, the procedure is more complicated because air leakage through party walls must be accounted for. This is eliminated by simultaneously depressurizing dwellings adjacent to the test dwelling.

More than 30 dwellings were tested for the survey. Detailed testing was carried out on one town house to quantify air leakage through various portions of the building envelope. Accessible leaks were sequentially sealed, and the dwelling was re-tested.

Working drawings were obtained for the dwellings tested, compared with actual construction details, and corrected where necessary. These are included in the report, providing a "benchmark" of

construction details used in town houses in Alberta.

Party walls were found to be major contributors to air leakage. While this is not a problem in terms of energy conservation, even small penetrations between dwellings substantially increase noise transmission. Air transfer between dwellings also results in air quality problems, as when cigarette smoke migrates to the dwellings of non-smokers. The degree of party wall leakage identified also indicates the need for testing methods that differentiate this leakage from outdoor leakage.

Envelopes of town houses were found to be leakier than those of single family dwellings. The sequential sealing study, which attacked accessible apertures in the envelope, only eliminated a minor portion of overall leakage. Further work needs to be done to determine whether leakage up through the party wall to attic spaces is the cause of poorer performance, or whether workmanship or other factors are the primary cause.

1. INTRODUCTION

1.1 Purpose of the Study

This study involved a survey of air tightness of town houses located in Calgary, Alberta. The goal was to compare the performance of town houses with that of detached dwellings, on which substantial information had already been collected by other researchers. In the course of the survey, air leakage points were located, and some experiments were conducted to determine the relative importance of air leakage paths. A further objective was to catalogue construction details for the town houses that were tested.

1.2 Problem Being Addressed

While a number of extensive surveys have been conducted on air leakage in single family dwellings (Dumont, 1981, Sulatisky, 1984), very little work has been conducted on row housing. No articles or reports have been encountered that deal with the air tightness of the existing town house stock in Canada. The only article found on air leakage in town houses in the United States measured natural air infiltration by the tracer gas method in one town house project (Socolow, 1978). As is discussed below, this method yields results that vary greatly from one weather condition to another.

A review of housing statistics for Calgary shows that its housing stock includes about 23 000 town house units - equivalent to 12 percent of the total number of dwelling units in the city. Approximately 75 percent of these town house units were built in

the 1976-82 period. Pressure testing of a couple of these town houses carried out in January, 1984 showed them to be much leakier than typical single family dwellings of the same vintage (circa 1978).

It is accepted that air leakage accounts for about 26% of heat loss in existing single family dwellings (Beck, 1977). Since town houses have proportionally less exposed surface area, it is believed that air leakage contributes proportionally even more to heat loss in such housing (Beck, 1977). If this is the case, then it is of even greater value to know the channels of air leakage in town houses than it is in single family dwellings.

Apart from possible contributions to heat loss, party wall leakage is of interest because air flow can transmit odours and contaminants between adjacent units. As well, air gaps contribute substantially to noise transmission between adjacent dwelling units.

1.3 Scope and Focus of the Study

Usable test results were obtained for 35 existing town houses from 8 projects by the fan depressurization technique (described in Section 2). Smoke pencils were used to locate typical air leakage points for each project. One town house was investigated in detail by gradually sealing identified and accessible air leakage points and retesting to quantify the significance of the various leakage paths.

1.4 Research Method

Air tightness can be determined by depressurizing dwelling units with a powerful fan and measuring pressure differentials across the building envelope and into the fan nozzle; analysis of the pressure readings together with information on unit size and weather yields indicators of leakiness. This is now a well-recognized technique (see CGSB, 1983). Testing town houses is more complex than testing single family dwellings because party wall leakage must be considered. In some studies of town house heat loss, party walls have been implicated as substantial air leakage channels (Bliss, 1984).

1.5 Organization of the Report

Section 2 reviews the methodology used in pressure testing. Section 3 covers the survey of town house air tightness. Section 4 deals with the quantification of relative importance of air leakage paths. Section 5 reports conclusions. Appendix C contains the catalogue of town house details.

2. METHODS FOR TESTING AIR LEAKAGE

There are two common methods for evaluating the air tightness of buildings. One involves measuring the rate at which the concentration of a gas released into the interior of a building decreases; this is referred to as the "tracer gas" technique. It may be performed with a single injection of gas for a quick measurement, or with periodic injections and continuous monitoring of the concentration of the gas. The problem with the former is that natural air change in buildings varies greatly with wind speed and direction, and with the inside-outside temperature differential. Hence a single test may not accurately represent the average infiltration rate. The continuous approach overcomes this difficulty but is relatively costly.

Pressure testing of envelopes was developed as an alternative to tracer gas techniques. The building is pressurized and/or depressurized by a powerful fan. The leakier the building envelope, the more air will be drawn through it at a given inside-outside pressure differential. The air change rate, that is the number of times in an hour the volume of air in the house would be replaced by outside air, can be calculated from pressure readings taken in a calibrated fan nozzle. A recognized standard for rating envelope leakiness is the air change rate at a pressure differential of 50 pascals across the building envelope (AC50). For instance, certification requirements for R2000 homes specify that AC50 be less than 1.5.

The advantage of pressure testing is that it gives a relatively repeatable measure of envelope tightness. It can also be performed over a relatively short period of time and at a relatively modest cost. Due to the complexity of air flow in buildings, it is not possible to make an exact deduction of natural air change from results of pressure testing. Pressure testing is more useful in making relative comparisons between buildings.

Pressure testing is limited in accuracy as a measure of air tightness by seasonal variations in envelope leakiness. These variations are the result of changes in the moisture content of the wood frame of the dwelling, and may result in variations in air tightness measurements as great as 25% (Persily, 1984).

Wind can be a serious problem in pressure testing. As wind speeds exceed about 10 km/h, pressure gauges begin to fluctuate. Valid readings can be obtained by taking readings during lulls (if they occur), but this lengthens the testing procedure and requires redundant tests to ensure accuracy. On several occasions, the researchers had to cancel scheduled tests or abandon tests underway due to wind conditions.

Typically, at least half a dozen fan nozzle pressure measurements are made at a series of indoor-outdoor pressure differentials (i.e. from 5 Pa to 50 Pa). Data generated by the series of readings is used as a check to ensure that a valid measurement of the envelope leakiness has been made (see CGSB, 1985). Apart from AC50, other indicators of envelope air tightness may be generated from field data. These include:

(i) Equivalent Leakage Area (ELA)

This is approximately the total leakage area of all the leakage openings in the envelope of the house (see Appendix A for detailed information on calculation of ELA). A large percentage of North American homes have an ELA of about 0.1 square metres (Enercorp, 1984, P.79).

(ii) Normalized Leakage Area (NLA)

To permit comparison of leakage areas for dwellings of different sizes, NLA was devised. Envelope leakiness is rated in terms of leakage area per area of envelope; this makes the comparison of buildings such as town houses with buildings such as single family dwellings more accurate. NLA is defined as:

(ELA x 10000)/exposed surface area of dwelling

The units of measurement are square centimetres of leakage area per square metre of envelope area

(cm^2/m^2).

(iii) Relative Tightness (RT)

Another measure devised for comparison of buildings of different sizes is RT. In this case, the dwelling is rated in terms of air flow through the envelope per unit of envelope area. It is defined as:

Q10/exposed surface area of building

where Q10=air flow through the envelope at 10 pascals pressure differential

The units of measurement are litres per second per square metre of envelope area ($l/s\ m^2$).

Each of these measures has its advantages and disadvantages. Normalized Leakage Area and Relative Tightness give normalized measures of performance which makes it possible to compare dwellings of different surface areas on a comparable basis. However,

they are based on a range of pressure readings, so can be less accurate when based on results obtained under windy conditions. AC5Ø is not as useful in comparing dwellings that differ in surface area, but it is less subject to influences of wind because the number is based on air flow under substantial fan pressure - wind is relatively less important.

2.1 Pressure Testing of Town Houses

As was mentioned in the introduction, pressure testing of town houses is more complicated than pressure testing of single family dwellings because it is desirable to differentiate between leakage of air through party walls and leakage of air through the exterior building envelope. The leakage of the whole envelope, including party walls can be found by conducting a pressure test as would be done for a single family dwelling. Leakage across party walls can be eliminated by simultaneously depressurizing the adjacent dwelling units.

One additional fan is necessary to eliminate party wall leakage for an end unit, or two additional fans to equalize pressure for a "middle of the row" unit. The fan operators communicate by walkie-talkie and set the fan speeds so that all dwellings are kept at the same indoor-outdoor pressure differential while readings are taken.

2.2 Complications in Testing of Town Houses

Apart from the need to coordinate the operation of two or three fans, there are other complications that must be dealt with in testing of row housing. To obtain equalized pressure readings for a given town house, access must be gained to adjacent units as well as test units. This requires the cooperation of a number of homeowners or tenants, and a time must be found that suits all participants. This can be difficult to arrange. The researchers also, on one occasion arrived at the test site to find that one of the participants had changed his mind.

Prior to testing of any building for air tightness, all intentional openings in the envelope must be sealed. For instance, intentional openings in residential buildings include dryer, bathroom and kitchen range vents, fresh (make-up) and combustion air ducts, and furnace and hot water heater flues (after shutting off the appliances, of course). In order for the fans in units neighbouring the test unit to maintain similar pressures, the same preparation must usually be undertaken. This increases the time required for testing over what is required in the case of single family dwellings.

3. RESULTS OF AIR TIGHTNESS SURVEY

Thirty-five town houses from 8 different projects were included in the overall sample. As is evident from the earlier estimate of the town house population in Calgary, this is a very small sample population relative to the total town house population in Calgary. Table B.1 on page 26 contains descriptions of the units tested; Table B.2 on page 27 indicates the spatial clustering of the units tested. Tables B.3 through B.6 on pages 28 through 31 provide detailed data obtained through the testing carried out by the researchers.

Table 3.1. Summary of Statistics for Town House Air Leakage (AC5Ø)

	Interior Units								End Units		
Date Built	Adjacent Units Unequalized		1 of 2 Walls Equalized			Both Walls Equalized			Adjacent Units Equalized		
	Sample Size	AC50	Sample Size	Drop in AC50		Sample Size	Drop in AC50		Sample Size	Drop in AC50	
pre-75	9	5.2	3	1.5	26%	0	-	-	3	1.1	23%
75-82	9	7.8	1	1.7	19%	2	3.7	61%	1	2.6	30%
82+	16	5.2	4	0.9	23%	5	2.6	38%	3	1.7	31%
all	34	5.9	8	1.2	24%	7	2.6	45%	7	1.6	27%
standard deviation		4.1									

Note: The drop in air change is relative to the air change with the adjacent units unequalized. The overall percentage drop is the average of the 3 age group figures weighted by sample size.

Tables 3.1 (above) and 3.2 (on page 1Ø) summarize AC5Ø and ELA data for the town houses studied; the information is broken down by date of construction as requested by Alberta Housing.

Table 3.2. Summary of Statistics for Town House Air Leakage (ELA)

Date Built	Interior Units: Adjacent Units Unequalized		Interior Units: 1 of 2 Walls Equalized			Interior Units: Both Walls Equalized			End Units: Adjacent Units Equalized		
	Sample Size	ELA (cm2/m2)	Sample Size	Drop in ELA (cm2/m2)	%	Sample Size	Drop in ELA (cm2/m2)	%	Sample Size	Drop in ELA (cm2/m2)	%
pre-75	9	0.065	3	0.005	8	0	-	-	3	0.003	5
75-82	9	0.089	1	0.023	21	2	0.042	42	1	0.027	30
82+	16	0.066	4	0.015	24	5	0.037	37	3	0.021	.29
all	34	0.072	8	0.012	18	7	0.032	38	7	0.014	19

Note: The drop in air change is relative to the air change with the adjacent units unequalized. The overall percentage drop is the average of the 3 age group figures weighted by sample size.

3.1 Seasonal Variation in Measurements

Unit 7-2 was tested in January and in July, with AC50 of 5.5 in the former case and 5.3 in the latter, a difference of less than 4 percent. This would suggest that seasonal variations in the sample are not great.

3.2 Equalization Effects

The importance of correcting for party wall leakage is evident. When adjacent units were equalized, air changes at 50 pascals pressure differential across the building envelope were reduced, on average, by 45% in interior units and 27% in end units (see Table 3.1 on page 9). This was equivalent to a drop of 2.6 air changes per hour in the former case and 1.6 air changes per hour in the latter case. The average drop in AC50 when interior units were equalized on one side was therefore about half that when

equalized on both sides. The differences allow differentiation of air leakage attributable to party walls and to the exterior building envelope, and are discussed later in this report.

3.3 Variations within the Sample

3.3.1 General

One of the most noticeable results is the relatively poor performance of housing in the 75-82 period compared with either older or more recently built housing (equalized AC50 of 5.9 versus 3.4). However, the sample size is too small to generalize to the entire population with any degree of confidence.

3.3.2 Project 7

Eleven units were tested from project 7, allowing for more detailed intra project comparisons than for other cases. Fully equalized tests were conducted on 7 of these 11 units, 5 of which were interior units and 2 of which were end units. The range in AC50 (equalized) for interior units was 100% - from 2.2 to 4.4. With the two units on which extensive sealing had been undertaken by the owners excluded (7-6 and 7-9), the range decreased from 3.8 to 4.4, or 15%. AC50 (equalized) for the end units fell within the same range as for the interior units

On the basis of NLA, the variation was greater - from 3.0 to 4.5 cm^2/m^2 for the interior units (excluding the two special cases), with an average of 3.6 cm2/m2. NLA for the two end units was 2.4 and 2.6 cm^2/m^2. Hence the end units are clearly more air tight than the interior units. The reason for this is not known.

3.4 Comparison with Results of Other Studies

3.4.1 Dumont Saskatoon Study

Dumont reports a mean AC50 of 3.6, with a standard deviation of 1.3, for 97 single family dwellings built between 1961 and 1980 in the Saskatoon area (Dumont, 1981). This is comparable to the average of 3.9 obtained for 15 town houses of all ages tested under equalized conditions. If results for town houses with particularly poor construction are dropped, the average becomes 3.4. Dumont also notes a mean AC50 of 1.5, with a standard deviation of 0.9 for 40 recently constructed low energy houses in the same area. Units 7-6 and 7-9 came within 50% of this figure under equalized conditions.

Dumont, in the same study, reported a relative tightness of 0.61 l/s m^2 (standard deviation 0.22) for the 1961-80 group of homes. The average relative tightness for equalized interior units in this study was 1.0 l/s m^2, and 0.75 l/s m^2 for end units (7 units in each category). The overall average relative tightness was 0.87 l/s m^2, 43% worse than for the single family dwellings. This drops to 0.70 l/s m^2 if the two poorly built projects are dropped - still significantly worse than for single family dwellings.

3.4.2 Sulatisky Canada-wide Study

Sulatisky summarized results of testing of 200 new houses from across Canada (Sulatisky, 1984). He reports a mean AC50 of 4.8 for the full sample, and of 5.3 for 20 single family dwellings tested in Alberta. The Canada wide figure is 33% worse than Dumont's figures for older houses in Saskatoon! However, the 20 new houses tested in Saskatchewan had a mean AC50 of 2.2, which would suggest that Saskatchewan houses have always been built more air tight than houses built in other parts of Canada. Recently built town houses (1982 or later) tested were found to be much tighter than this (AC50 of 3.4 for 8 units tested under equalized conditions).

Sulatisky, in the same study, reported an average normalized leakage area of 2.9 cm^2/m^2. This compares with 3.0 cm^2/m^2 for town house end units and 3.7 $cm2/m2$ for interior units (7 in each category) for an overall average of 3.4 $cm2/m^2$ - only 17% worse than the figure cited in Sulatisky's study. Sulatisky cites a normalized leakage area of 3.9 cm^2/m^2 for the Alberta single family dwellings, compared with 3.3 $cm2/m2$ found for 7 recently built (1982 or later) town houses from project 7 (under equalized conditions).

3.5 Envelope Details

Appendix C contains a catalogue of envelope details for the projects tested.

4. RELATIVE CONTRIBUTION OF AIR LEAKAGE PATHS

4.1 Smoke Pencil Survey of Units

As each town house project was tested, smoke pencils were used to detect air leakage paths. Of course, this only provides non-quantitative information on air leakage paths, but it is a very quick and economical way to examine leakage. Very distinct leakage paths were found to exist at:

(i) electrical outlets (both party and exterior walls),

(ii) ceiling mounted light fixtures next to attic spaces,

(iii) sill plates (both party and exterior walls),

(iv) window units (both at slider joints and frames), and

(v) basement gaps in party walls (beam seats, pipe runs).

4.2 Deductions from the Survey of Air Tightness

In the cases where it was possible to conduct fully equalized tests on town houses, leakage attributable to party walls and exterior envelope areas could be clearly distinguished. Table B.3 on page 28 shows results for 14 town house units for which this was possible.

4.3 Detailed Study of Leakage in a Town House Unit

4.3.1 Study Procedure

Interior town house unit 7-2 was exhaustively tested for a period of 8 hours. Both equalized and unequalized pressure tests were conducted according to the CGSB standard procedure (CGSB, 1983). Then, detectable and accessible leakage points were sealed step by step, and re-tests were conducted. Masking tape was used for the sealing work, except as otherwise noted below. The sealing was limited by obstructions that could not be removed such as:

(i) plumbing and stairs against party wall,

(ii) personal possessions of occupants, and

(iii) drywall extending below sill plate on party wall (was taped at bottom to basement concrete wall to achieve a seal).

(iv) insulation and drywall extending below the sill plate on the exterior wall, rendering the sill plate inaccessible.

The order and steps in the sealing were as follows:

(i) Seal electrical outlets and other outlets in party walls of adjacent units (7-1 and 7-11).

(ii) Seal electrical outlets and other outlets in party walls of unit 7-2. The intention in doing (i) and (ii) in sequence was to determine whether air was leaking through party walls from outdoors or across from adjacent units.

(iii) Seal detectable leaks in basement where accessible (virtually all accessible basement wall leaks were on party walls).

(iv) Seal openings in interior partitions (including electrical outlets and drywall penetrations for piping.

(v) Seal electrical outlets and other outlets in exterior walls of test unit.

(v.) Seal windows and patio (sliding glass) doors with plastic sheeting by taping to frame (no test was done sealing at edges of frames since almost no leakage could be detected at this point).

(vi) Seal gaps in attic. This was limited by 15 cm or more of blown-in fibreglass insulation. Only plumbing vents were located (light fixtures could not be readily located). However, one hole on the ceiling 0.090 square metres in area (0.6 m by 0.15 m aperture) was found leading into an enclosed space behind the bathroom (see Figure C.7b on page 51). This was sealed.

4.3.2 Study Results

Results of this testing are summarized in Table 4.1 on page 18. Some results appear anomalous (higher AC50 or ELA after implementation of a sealing step than before). In the case of AC50, the variations are no more than 0.1, which is within the range of error of the measurement technique. In the case of ELA, the variations are likely due to wind effects. AC50 is less susceptible to these effects since the envelope is under maximum forced pressure and hence is least susceptible to wind effects.

Scanada Consultants reviewed results from step-by-step sealing and air tightness testing of 15 detached dwellings and experienced similar problems (1984) with negative reductions. They simply assigned a zero value to tightness changes in such instances.

The equivalent leakage area attributable to the party walls was found to be 0.014 m^2, and 0.058 m^2 for the exterior envelope. Electrical and other outlets on the party walls appeared to have

Table 4.1. Summary of Results from Detailed Testing of Unit 7-2.

Sealing Stage	Air Changes @ 50 Pa	Equivalent Leakage Area (m2)	Normalized Leakage Area	Relative Tightness
31 baseline unequalized	5.4*	0.079	5.3*	1.3*
30/32 pty. wall elec. outlets	5.5	0.070	6.5	1.6
31 party wall elec. outlets	5.5	0.080	6.5	1.6
31 basement pty. wall leaks	4.9	0.075	5.8	1.4
31 interior partition gaps	4.8	0.070	5.5	1.3
31 exterior wall elec. outlets	4.9	0.067	5.2	1.3
31 windows	4.6	0.061	4.7	1.2
31 ceiling (attic side)	4.4	0.064	5.0	1.2

* These numbers are suspect, given that the next test resulted in higher values although minor air-tightening had been undertaken; the second set of numbers are likely more representative.

little impact on overall performance. The taping of the basement party wall leakage areas generated a reduction that would suggest that the basement sill plate and penetrations through the basement wall are the major channel of air flow between units.

Sealing of gaps in interior partitions also resulted in a small but detectable drop in air leakage, as did sealing of exterior envelope outlets and windows The total sealing resulted in a drop in AC50 of 1.0 (18%) and in ELA of .015 (19%). This leads to the tentative conclusion that the majority of the air leakage is through channels that are well-distributed and not readily

accessible. The conclusion is qualified as tentative because of the anomalies attributed to wind. It should be noted that correlation coefficients (r-squared) for all tests performed in this sub-study exceeded Ø.99Ø.

4.3.3 Reassessment of Smoke Pencil Technique

Certain areas appeared to have dramatic air leakage when detected by smoke from smoke pencils while dwellings were depressurized. For instance, electrical outlets appeared to be admitting substantial fresh air. However, when these types of openings were sealed and the resulting pressure drop measured, they were found to be relatively insignificant. This would suggest that the smoke pencil is only a very crude and inaccurate indicator of the significance of an air leak.

4.3.4 Comparison of Results with Other Studies

A report by Scanada Consultants on step-by-step sealing of single family dwellings was referred to above. Unfortunately, due to problems with testing and variability in construction, Scanada were not able to report on the individual measures such as sealing gross leaks in basements, sealing fine leaks in basements, and so on.

RPG consultants of Calgary undertook a study of air-sealing of homes in the Calgary area (Johnson, 1985). The age of the houses varies much more than for the sample of town houses in this study; most dwellings are detached. The most significant areas to seal, in terms of air-leakage reduction, were found to be:

(i) door and window frames, envelope penetrations for light fixtures, and attic hatch and

(ii) joist header (or band joist) joints.

However, each of these measures reduced AC50 by no more than 5% on average. All sealing measures reduced AC50 by 26% on average.

5. CONCLUSIONS

5.1 Assessment of Workmanship

The sample of town houses tested was found to have mean air changes per hour at 50 Pascals pressure differential across the envelope comparable to or better than those determined for single family dwellings of the same vintage. However, a great range (AC50 from 2.2 to 6.1 under equalized conditions) was found to exist within the sample. Two projects built in the 1975-82 period were found to have particularly poor performance. Normalized leakage area and relative tightness, two measures which provide a more comparable rating of performance by considering exposed envelope area, showed the town houses studied to have leakier envelopes than single family dwellings tested by other researchers.

One surprising finding was that end units had tighter envelopes than interior units. This may be a result of party wall effects - if additional party walls result in additional leakage even under equalized conditions.

The two poorly built units differed in terms of air leakage problems. Project 8 had clearly deficient construction - infrared

scanning revealed gaps in the vapour barrier, and inspection of areas behind decorative trim (e.g. around a corner fireplace) revealed large gaps to the exterior. Project 5 had cathedral ceilings over the upper rooms; joints between walls and the ceiling were found to be poorly sealed (drywall butted against tongue and groove cedar). It was also the only project in which joists ran from party wall to party wall, rather than from front of dwelling to the rear. This may allow air to flow more freely through party walls.

In unit 7-2, the unit for which step-by-step sealing and testing was conducted, a hole 0.2 m^2 in area was found in the attic in the course of sealing (see Figure C.7b on page 51). It led into a space at the head of the bathtub. It appeared to be a major defect, but sealing it made little difference in the air flow rate under pressure.

5.2 Ranking of Air Leakage Routes

The fact that certain leakage routes found important in studies of single family dwellings were inaccessible in dwellings investigated by these researchers requires some qualification of the following results. In particular, drywall and insulation on the exterior wall made the sill plate inaccessible. It would be useful to repeat the step-by-step testing procedure in a unit where more extensive physical modifications could be undertaken (such as removal and replacement of basement insulation).

The detailed study, undertaken to quantify the relative magnitude

of air leakage routes, found electrical and communication outlets to be insignificant. Holes for plumbing, sill plate joints, and windows were moderately important. The bulk of the leakage appeared to be widely distributed around the envelope. Since the investigators were limited to non-destructive testing, location of these holes was not possible. Further investigation of air leakage channels and sealing measures would be useful in determining the nature of these leaks and their possible treatment.

It should be noted that, without pressure equalization, substantial leakage occurs across the party wall. The reduction in AC50 for interior units when tested under equalized conditions ranged from 29 to 52, and averaged 52 percent. Most of the leakage between units appears to occur at the sill plate between units. When the sill plate in unit 7-2 was sealed, in the course of the step-by-step sealing test, an 11 percent reduction in AC50 (under unequalized conditions) resulted. Since sealing was limited by various obstructions in the tested unit, it is likely that this one channel was accountable for much more than 11 percent of inter-unit leakage. Other party wall leakage points were noted at beam seats in the foundation and inter-unit piping penetrations.

5.3 Summary

It is clear that party walls represent substantial air leakage routes, and must be corrected for air tightness testing of row housing units. It appears that air leakage on the exterior envelope is distributed over a large number of small leaks rather than being the result of a small number of large gaps. This limits the extent to which a basic sealing effort can increase the air tightness of the units. Units built 10 years ago were found to be as air tight as recently built housing; noticeably poorer performance was found in the case of two projects built in the 1975-82 period.

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APPENDIX A: Equations Used to Generate Information from Field Tests

The air flow through the calibrated fan nozzle may be described by the following equation:

$$Q = C_{\Delta}P^{n}$$

where Q = volumetric flow rate of air (l/s)
C = flow constant for test dwelling (l/s Pa)
n = flow exponent
$_{\Delta}P$ = differential pressure across envelope (Pa)

Equivalent Leakage Area is then defined by the equation:

$$ELA = 0.001157 \quad p\ C\ (10^{n-0.5})$$

where p = the density of the outdoor air

APPENDIX B: Detailed Data from Pressure Tests

Table B.1. Physical Characteristics of Units Tested

Unit Description					
Unit Code	Construction Date	Floor Area (m2)	Volume (m3)	Unit Configuration	
1-1	pre-75	99	376	2S-E	
1-2	pre-75	99	376	2S-I	
1-3	pre-75	99	376	2S-I	
2-1	pre-75	83	324	2S-E	
2-2	pre-75	83	324	2S-E	
2-3	pre-75	83	324	2S-I	
2-4	pre-75	83	324	2S-I	
3-1	pre-75	81	198	BL-E	
3-2	pre-75	81	198	BL-I	
4-1	75-82	106	367	2S-E	fireplace
4-2	75-82	109	372	2S-E	fireplace
4-3	75-82	109	375	2S-I	fireplace
5-1	75-82	102	300	3S-E	carport/storage at grade
5-2	75-82	90	271	3S-I	carport/coop office at grade fireplace
5-3	75-82	91	234	3S-I	carport/storage at grade
5-4	75-82	91	234	3S-I	carport/storage at grade
6-1	82+	94	354	2S-I	
6-2	82+	96	356	2S-E	rows end with 2 back to back L-shaped units
6-3	82+	96	356	2S-E	
6-4	82+	94	354	2S-I	
6-5	82+	94	354	2S-I	
6-6	82+	94	354	2S-I	
7-1	82+	100	372	3S-E	lower story below grade at rear
7-2	82+	100	372	3S-I	lower story below grade at rear
7-3	82+	100	372	3S-E	lower story below grade at rear
7-4	82+	100	372	3S-I	lower story below grade at rear
7-5	82+	100	372	3S-I	lower story below grade at rear
7-6	82+	100	372	3S-I	lower story below grade at rear
7-7	82+	100	372	3S-I	lower story below grade at rear
7-8	82+	100	372	3S-I	lower story below grade at rear
7-9	82+	100	372	3S-I	lower story below grade at rear
7-10	82+	100	372	3S-E	lower story below grade at rear
7-11	82+	100	372	3S-I	lower story below grade at rear
8-1	75-82	91	294	3S-E	carport at grade/fireplace
8-2	75-82	99	317	3S-E	carport at grade/fireplace

Key: 2S=2 story; 3S=3 story; BL=bilevel; SL=split level
E=end unit; I=interior unit

Table B.2. Spatial Relationship of Units Tested

1-1(E), 1-2(I)

1-3(I)

2-1(E), 2-4(I)

2-2(E), 2-3(I)

3-1(E), 3-2(I)

4-1(E)

4-2(E)

4-3(I)

5-1(E), 5-2(I), 5-3(I), 5-4(I)

6-2(E):
6-3(E):6-1(I)

6-5(E), 6-4(E), 6-6(E)

7-11 (I),7-2(I),7-1(E)

7-4(E),7-3(I)

7-5(E), 7-6(I), 7-7(I), 7-8(I), 7-9(I), 7-10(E)

8-1(E)

8-2(E)

Table B.3. Pressure Test Results for Unequalized and Equalized Tests (all party walls equalized).

Unit Code	Date Built	Air Changes @ 50 Pa		Equivalent Leakage Area (m2)		Normalized Leakage Area		Relative Tightness	
		#1	#2	#1	#2	#1	#2	#1	#2
1-1	pre-75	4.4	3.4	0.064	0.041	3.9	2.5	0.95	0.63
1-2	pre-75	6.2		0.101		8.4		2.8	
1-3	pre-75	5.6		0.091		7.5		1.8	
2-1	pre-75	3.4	2.8	0.050	0.044	3.4	3.0	0.85	0.75
2-2	pre-75	3.4	2.5*	0.041	0.028*	2.7	1.9*	0.67	0.46
2-3	pre-75	4.6		0.060		5.7		1.4	
2-4	pre-75	6.8		0.075		7.2		1.8	
3-1	pre-75	6.3	4.6	0.050	0.043	4.4	3.8	1.1	0.96
3-2	pre-75	6.7		0.053		6.9		1.7	
4-1	75-82	5.3		0.074		4.2		1.8	
4-2	75-82	4.3		0.054		3.1		0.79	
4-3	75-82	4.6		0.051		3.8		0.96	
5-1	75-82	8.5	5.9*	0.098	0.063*	5.1	3.5*	2.2	1.6
5-2	75-82	8.8	5.7*	0.091	0.052*	6.2	3.6*	2.6	0.91
5-3	75-82	10.4	6.1	0.108	0.068	6.9	4.8	2.8	1.6
5-4	75-82	8.3		0.102		6.5		2.7	
8-1	75-82	9.2		0.100		9.1		2.2	
8-2	75-82	11.3		0.130		11.5		2.8	
6-1	82+	3.8		0.034		3.0		0.77	
6-2	82+	5.3	3.2	0.078	0.052	5.2	3.5	1.2	0.88
6-3	82+		2.9		0.039		2.4		n/a
6-4	82+	3.6		0.048		4.0		1.0	
6-5	82+	4.5		0.056		4.6		1.1	
6-6	82+	4.5		0.059		4.8		1.2	
7-1	82+	5.7		0.075		3.9		0.92	
7-2	82+	5.5	3.9	0.065	0.058	5.0	4.5	1.22	1.14
7-3	82+	6.4		0.083		6.4		1.6	
7-4	82+	5.6	3.8	0.077	0.046	4.0	2.4	1.46	0.88
7-5	82+	5.3	4.1	0.066	0.052	3.4	2.7	1.31	1.03
7-6	82+	4.6	2.2	0.059	0.030	4.7	2.4	1.22	0.62
7-7	82+	6.2	3.9	0.088	0.062	6.8	4.8	1.7	1.07
7-8	82+	6.7	4.4	0.084	0.054	6.5	4.2	1.7	1.08
7-9	82+	4.3	2.5	0.073	0.038	5.7	2.3	1.4	0.58
7-10	82+	6.6		0.070		3.6		0.91	
7-11	82+	5.5		0.061		4.7		1.2	

Notes: #1 - results based on depressurization of test unit only

#2 - pressure equalized in adjacent units

* - CGSB requires r >0.990; for 2-2 r was only 0.967, for 5-1 r was only 0.983, for 5-2 r was only 0.987

Table B.4. Pressure Test Results for Unequalized and Partially Equalized Tests (not all party walls equalized).

Unit Code	Date Built	Air Changes @ 50 Pa		Equivalent Leakage Area (m2)		Normalized Leakage Area		Relative Tightness	
		#1	#2	#1	#2	#1	#2	#1	#2
1-1	pre-75	4.3		0.064		3.9		0.95	
1-2	pre-75	6.2		0.101		0.4		2.0	
1-3	pre-75	5.6		0.091		7.5		1.8	
2-1	pre-75	3.4		0.050		3.4		0.85	
2-2	pre-75	3.4		0.041		2.7		0.67	
2-3	pre-75	4.6	3.2	0.060	0.056	5.7	3.2	1.45	1.35
2-4	pre-75	6.0	4.1	0.075	0.050	7.2	4.0	1.0	1.3
3-1	pre-75	6.3		0.050		4.4		1.1	
3-2	pre-75	6.7	5.3	0.053	0.052	6.9	6.0	1.7	1.65
4-1	75-82	5.3		0.074		4.2		1.0	
4-2	75-82	4.3		0.054		3.1		0.79	
4-3	75-82	4.6		0.051		3.0		0.96	
5-1	75-82	8.5		0.090		5.1		2.2	
5-2	75-82	8.0	7.1	0.091	0.060	6.2	4.6	2.6	1.9
5-3	75-82	10.4		0.100		6.9		2.0	
5-4	75-82	8.2		0.104		6.6		2.7	
0-1	75-82	9.2		0.100		9.1		2.2	
0-2	75-82	11.3		0.130		11.5		2.0	
6-1	82+	3.0		0.034		3.0		0.77	
6-2	82+	5.3		0.071		4.7		1.2	
6-3	82+								
6-4	82+	3.6	2.0	0.040	0.030	4.0	3.1	1.0	0.79
6-5	82+	4.5	3.7	0.056	0.040	4.6	4.0	1.1	0.90
6-6	82+	4.5	3.5	0.059	0.044	4.0	2.0	1.2	0.70
7-1	82+	5.7		0.071		3.5		0.06	
7-2	82+	5.5		0.065		5.0		0.92	
7-3	82+	6.4	4.0	0.003	0.051	6.4	4.0	1.6	1.0
7-4	82+	5.6		0.072		3.6		0.92	
7-5	82+	5.3		0.066		3.2		0.02	
7-6	82+	4.6		0.059		4.7		0.00	
7-7	82+	6.2		0.005		4.7		1.3	
7-0	82+	6.6		0.004		4.7		1.2	
7-9	82+	4.3		0.060		3.9		1.0	
7-10	82+	6.9		0.069		3.4		0.09	

Notes: #1 - results based on depressurization of test unit only

#2 - pressure equalized on one side only

* - CGSB requires r > 0.990; for 2-2 r was only 0.967, for 5-1 r was only 0.983

Table B.5. Differences in Test Results for Equalized and Unequalized Tests - AC50 and ELA.

Unit Code	Date Built	Differences in Air Changes @ 50 Pa: Fully Equalized Actual	%	Equalized One Side Actual	%	Differences in Equivalent Leakage Area: Fully Equalized Actual	%	Equalized One Side Actual	%
1-1	pre-75	1.0	21			0.029	36		
1-2	pre-75								
1-3	pre-75								
2-1	pre-75	0.6	10			0.006	12		
2-2	pre-75	0.9*	26			0.013*	32		
2-3	pre-75			1.4	30			0.004	7
2-4	pre-75			1.6	32			0.011	15
3-1	pre-75	1.7	27			0.007	14		
3-2	pre-75			1.4	21			0.001	2
4-1	75-82								
4-2	75-82								
4-3	75-82								
5-1	75-82	2.6*	30			0.027*	30		
5-2	75-82	3.1*	35	1.7	19	0.039	43	0.023	25
5-3	75-82	4.3	41			0.046	42		
5-4	75-82								
6-1	82+								
6-2	82+	2.1	40			0.026	33		
6-3	82+								
6-4	82+			0.8	22			0.010	21
6-5	82+			0.8	10			0.000	14
6-6	82+			1.0	22			0.009	17
7-1	82+								
7-2	82+	1.6	29			0.007	11		
7-3	82+			1.6	25			0.032	30
7-4	82+	1.0	32			0.020	39		
7-5	82+	1.2	23			0.014	21		
7-6	82+	2.4	52			0.029	49		
7-7	82+	2.3	37			0.026	29		
7-8	82+	2.2	33			0.030	36		
7-9	82+	1.0	42			0.043	59		
7-10	82+								
7-11	82+								

Notes: #1 - results based on depressurization of test unit only

#2 - pressure equalized in adjacent units

* - CGSB requires r >0.990; for 2-3 r was only 0.967. for 5-1 r was only 0.983

Table B.6. Differences in Test Results for Equalized and Unequalized Tests - NLA and RT.

Unit Code	Date Built	Differences in Normalized Leakage Area: Fully Equalized Actual	Fully Equalized %	Equalized One Side Actual	Equalized One Side %	Differences in Relative Tightness: Fully Equalized Actual	Fully Equalized %	Equalized One Side Actual	Equalized One Side %
1-1	pre-75	1.4	36			0.32	34		
1-2	pre-75								
1-3	pre-75								
2-1	pre-75	0.4	12			0.10	12		
2-2	pre-75	0.8*	30			0.21	31		
2-3	pre-75			1.5	26			0.10	7
2-4	pre-75			2.8	29			0.50	28
3-1	pre-75	0.6	14			0.14	13		
3-2	pre-75			0.1	1			0.05	3
4-1	75-82								
4-2	75-82								
4-3	75-82								
5-1	75-82	1.6*	31			0.60	27		
5-2	75-82	2.6*	42	1.6	26	1.7	65	0.70	27
5-3	75-82	2.9	42			1.2	43		
5-4	75-82								
6-1	82+								
6-2	82+	1.7	33			0.32	27		
6-3	82+								
6-4	82+			0.9	22			0.21	21
6-5	82+			0.6	13			0.12	11
6-6	82+			2.8	42			0.50	42
7-1	82+								
7-2	82+	0.5	10			0.08	6		
7-3	82+			2.4	38			0.60	60
7-4	82+	1.6	48			0.58	48		
7-5	82+	1.3	28			0.60	49		
7-6	82+	2.3	49			0.43	49		
7-7	82+	2.8	29			0.73	43		
7-8	82+	2.3	35			0.72	42		
7-9	82+	3.4	60			0.82	58		
7-10	82+								
7-11	82+								

Notes: #1 - results based on depressurization of test unit only

#2 - pressure equalized in adjacent units

* - CGSB requires r >0.990; for 2-2 r was only 0.967, for 5-1 r was only 0.983

APPENDIX C: Catalogue of Town House Construction Details

This section contains a wall section for each of the interior and party walls for each project included in the air tightness survey.

Project 1

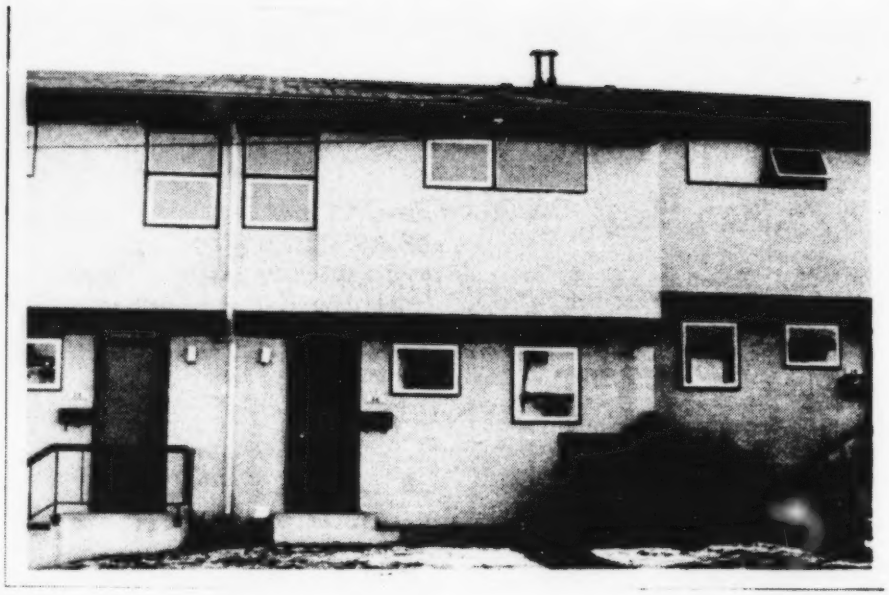


Figure C.1a. Photograph of a typical unit in Project 1.

One unit from the project was tested under equalized conditions; AC5Ø was found to be 3.4 which is only slightly higher than double the 1.5 maximum required under the R2ØØØ program. According to Scanada Consultants (1983), this is approaching the range where mechanical ventilation systems would have to be considered.

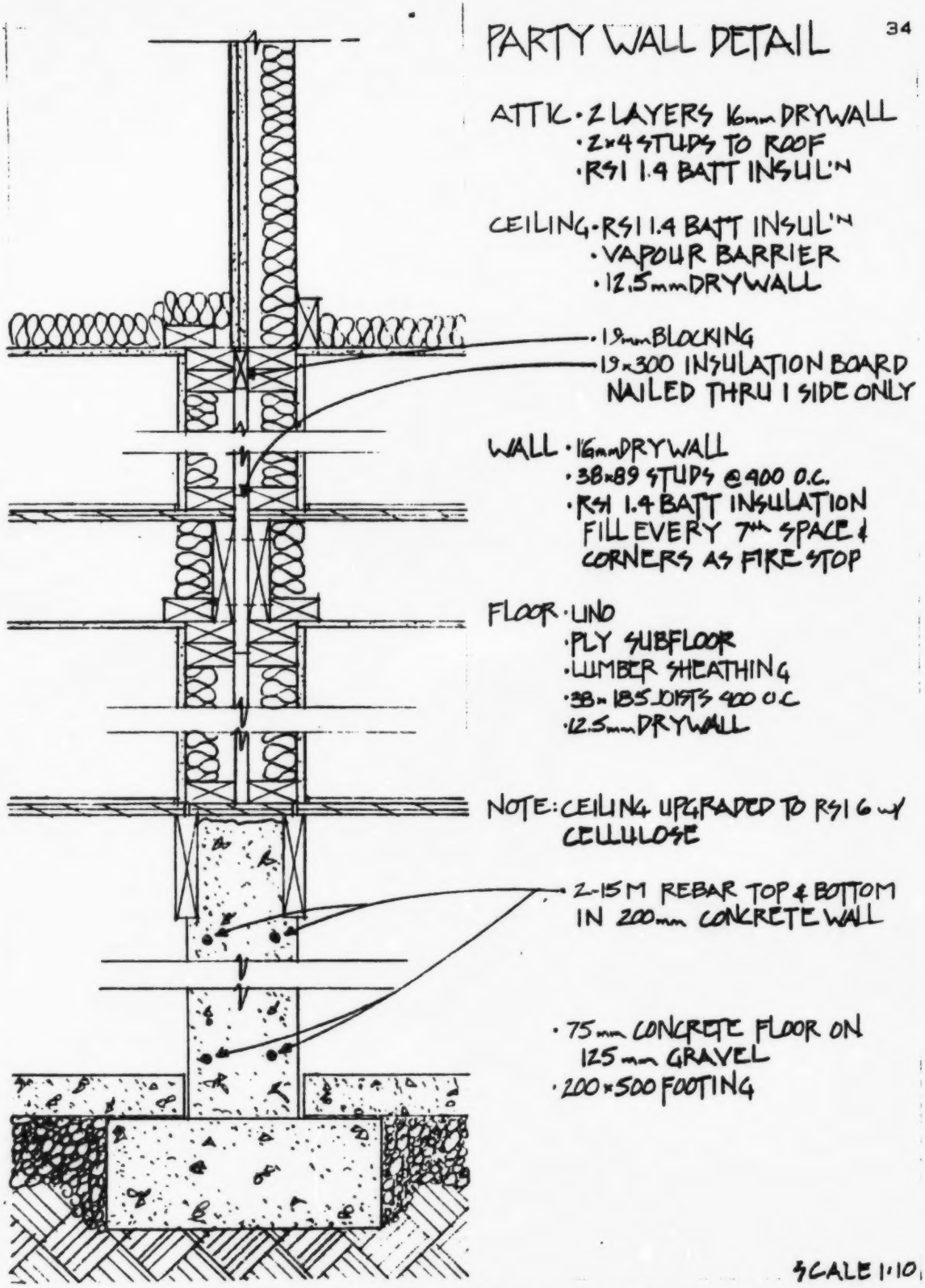


Figure C.1b. Party wall section for project 1.

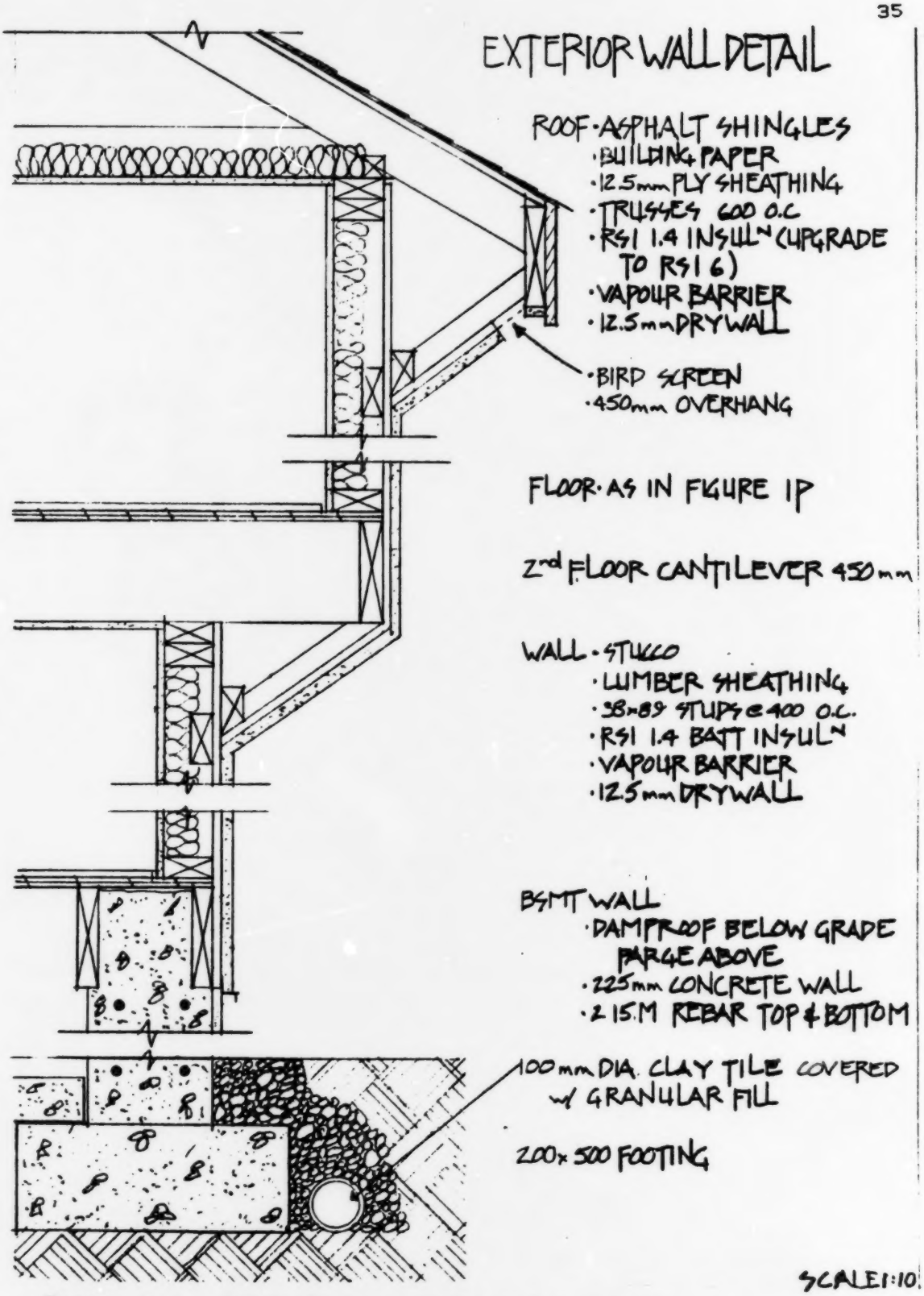
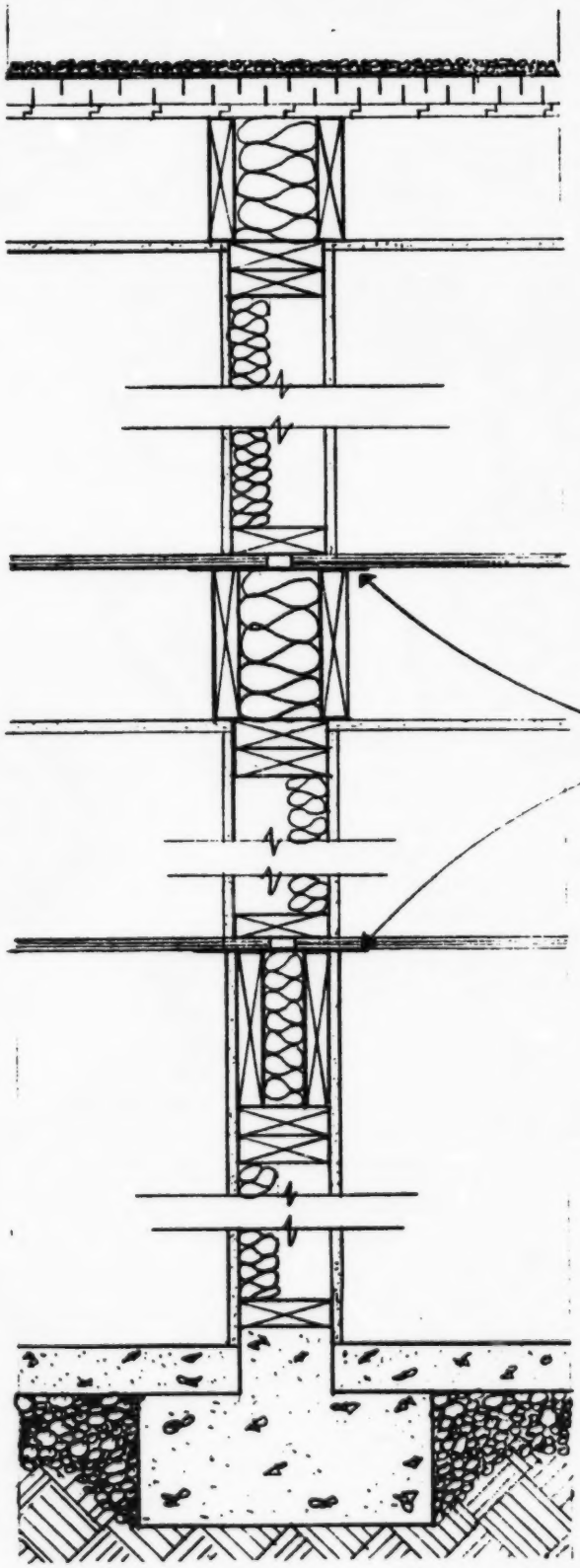

EXTERIOR WALL DETAIL
ROOF · ASPHALT SHINGLES
· BUILDING PAPER
· 12.5mm PLY SHEATHING
· TRUSSES 600 O.C.
· RSI 1.4 INSUL^N (UPGRADE TO RSI 6)
· VAPOUR BARRIER
· 12.5mm DRYWALL
· BIRD SCREEN
· 450mm OVERHANG
FLOOR · AS IN FIGURE 1P
2nd FLOOR CANTILEVER 450mm
WALL · STUCCO
· LUMBER SHEATHING
· 38x89 STUDS @ 400 O.C.
· RSI 1.4 BATT INSUL^N
· VAPOUR BARRIER
· 12.5mm DRYWALL
BSMT WALL
· DAMPROOF BELOW GRADE PARGE ABOVE
· 225mm CONCRETE WALL
· 2 15M REBAR TOP & BOTTOM
100mm DIA. CLAY TILE COVERED W/ GRANULAR FILL
200x500 FOOTING
SCALE 1:10

Figure C.1c. Exterior wall section for project 1.

Project 2

Figure C.2a. Photograph of a typical unit in Project 2.

Two units from the project were tested under equalized conditions; the average AC50 was found to be 2.7 which is less than double the 1.5 maximum required under the R2000 program. According to Scanada Consultants (1983), this is approaching the range where mechanical ventilation systems would have to be considered.



PARTY WALL DETAIL

ROOF
- BUILT UP ROOF
- 38 mm RIGID INSULATION
- 19 mm SHIPLAP
- 38 × 185 JOISTS
- VAPOUR BARRIER
- 12.5 mm DRYWALL

WALL
- 16mm FIREGUARD
- 62.5 mm BATT INSUL^{N}
- 38×89 STAGGERED STUDS @ 400 O.C ON 38×140 PLATES
- 16mm FIREGUARD

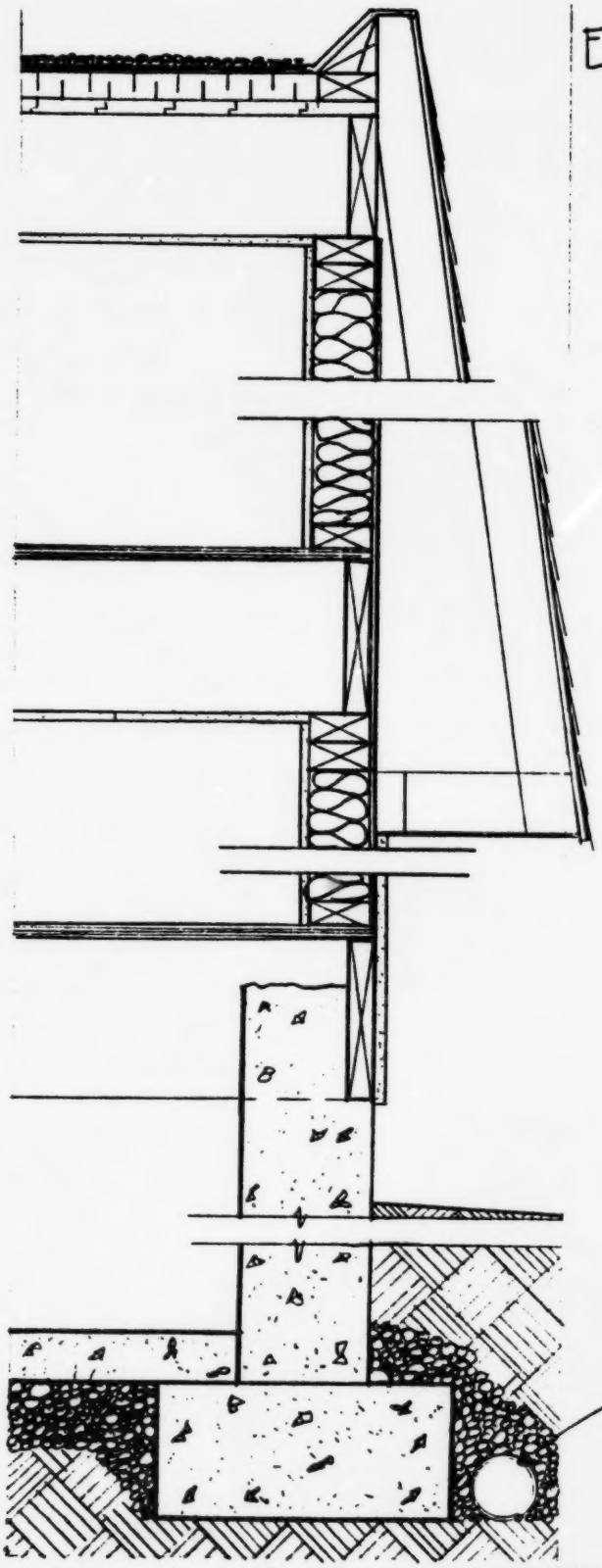
- METAL FIRESTOP

FLOOR
- FINISH FLOOR
- 16 mm T&G PLYWOOD
- 38×235 SPRUCE JOISTS @ 400 OC
- 12.5 mm DRYWALL

BASEMENT FLOOR
- 75 mm CONCRETE
- 125 mm GRAVEL
- FOOTING 200×450

SCALE 1:10.

Figure C.2b. Party wall section for project 2.



EXTERIOR WALL DETAIL

ROOF • AS IN FIGURE 2P

WALL • STUCCO ON LOOPWIRE & BUILDING PAPER
- 8mm PLY SHEATHING
- 38×89 STUDS @ 400 OC.
- RSI 2.4 BATT INSUL^N
- VAPOUR BARRIER
- 12.5mm DRYWALL

FLOORS • AS IN FIGURE 2P

BSMT WALL
- DAMPROOF BELOW GRADE PARGE ABOVE
- 200mm CONCRETE
- FOOTING • 200×450
- 100mm WEEPING TILE COVERED W/ CLEAN GRAVEL

SCALE 1:10

Figure C.2c. Exterior wall section for project 2.

Project 3

Figure C.3a. Photograph of a typical unit in Project 3.

One unit from the project was tested under equalized conditions; AC50 was found to be 4.6 which is triple the 1.5 maximum required under the R2000 program, and 50 percent higher than the average Dumont found for 97 single family dwellings built in the 1961-1980 period. The most notably different feature about these units was their flat roof construction. However, it was not possible to undertake sealing measures to determine whether this feature was the determining factor in the poorer performance (note that project 2 had flat roofs, but was quite air tight).

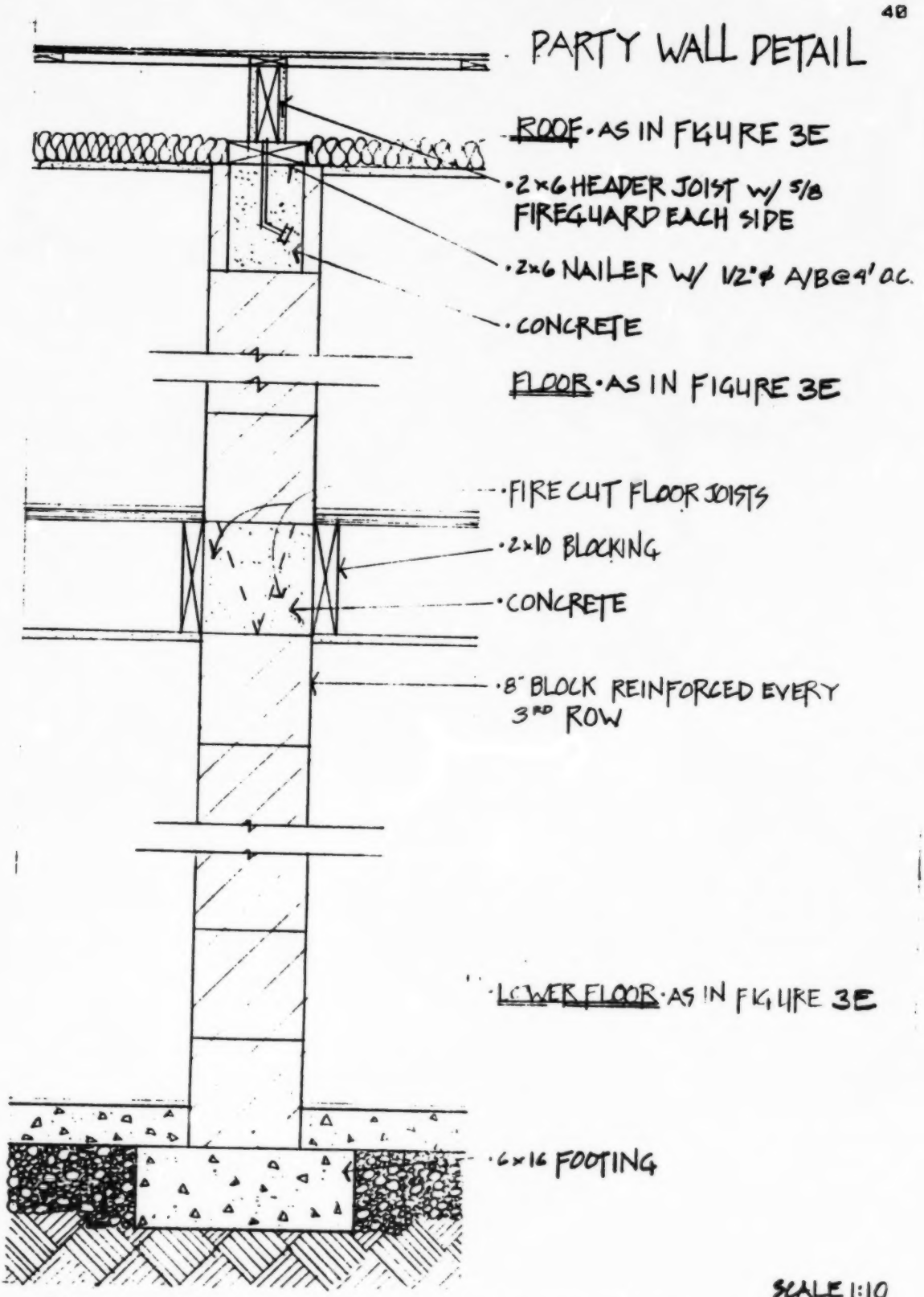
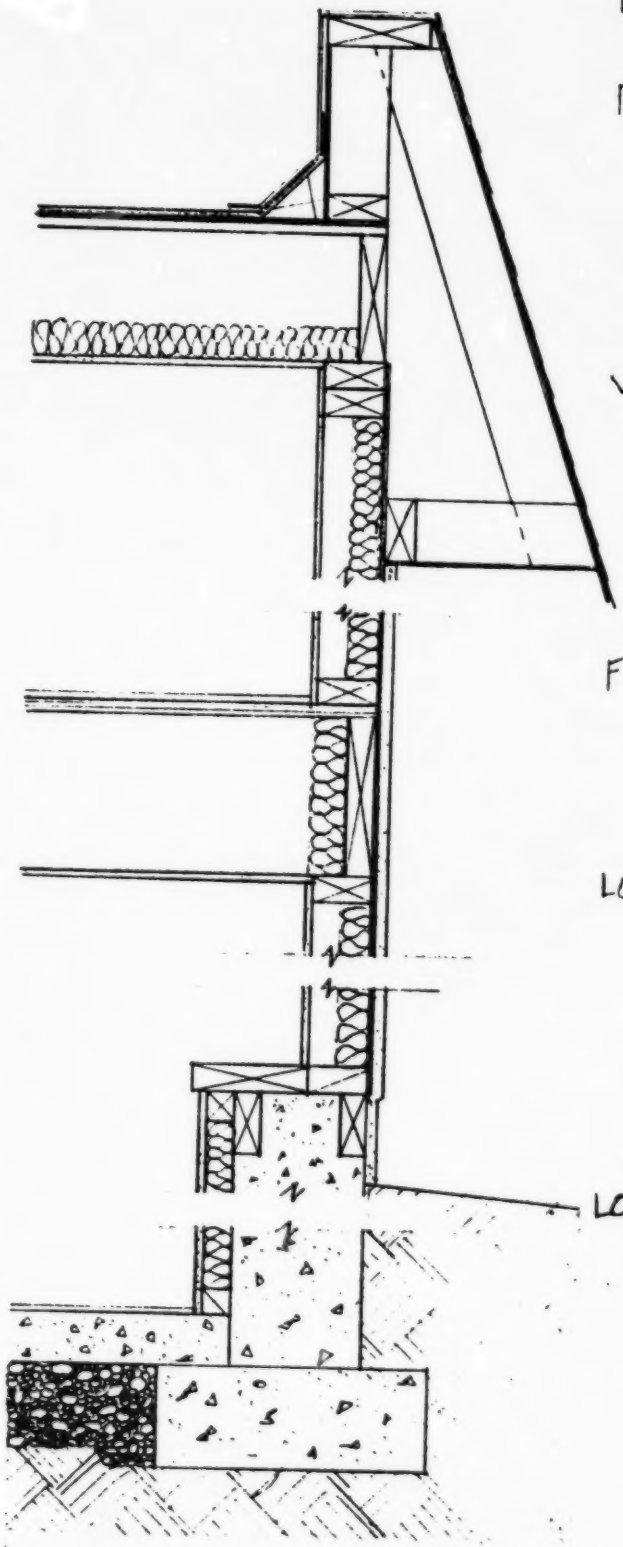

PARTY WALL DETAIL
ROOF · AS IN FIGURE 3E
· 2×6 HEADER JOIST w/ 5/8 FIREGUARD EACH SIDE
· 2×6 NAILER W/ 1/2"ϕ A/B@4' OC.
· CONCRETE
FLOOR · AS IN FIGURE 3E
· FIRE CUT FLOOR JOISTS
· 2×10 BLOCKING
· CONCRETE
· 8" BLOCK REINFORCED EVERY 3RD ROW
LOWER FLOOR · AS IN FIGURE 3E
· 6×16 FOOTING
SCALE 1:10

Figure C.3b. Party wall section for project 3.



EXTERIOR WALL DETAIL

ROOF
- BU. ROOFING
- 3/8 PLY SHEATHING
- 1×3 STRAPPING @ 16 O.C.
- 2×8 FIR JOISTS @ 24 O.C.
- R7 INSULATION
- V.B
- 1/2" DRYWALL

WALL
- STUCCO
- BUILDING PAPER
- 5/16" PLY STHG
- 2×4 STUDS @ 16 O.C.
- R7 INSULATION
- V.B.
- 1/2" DRYWALL

FLOOR
- FLOOR FINISH
- 5/16" K3 UNDERLAY
- 3/4" SUBFLOOR
- 2×10 SPRUCE JOISTS @ 16 O.C.
- 1/2" DRYWALL

LOWER WALL
- PARGE ABOVE GRADE
- DAMPROOF BELOW GRADE } O.S.
- 8" CONC WALL
- DAMPROOF BELOW GRADE I.S.
- 2×2 FURRING @ 24" O.C.
- R7 INSULATION
- V.B
- 1/2 DRYWALL

LOWER FLOOR
- FINISH FLOOR
- 3" CONC FLOOR
- 6 MIL POLY
- 5" CRUSHED GRAVEL

SCALE 1:10

Figure C.3c. Exterior wall section for project 3.

Project 4

Figure C.4a. Photograph of a typical unit in Project 4.

It was not possible to perform an equalized test for units in this project. The average AC5Ø (unequalized) of 4.7 is equivalent to about 3.5 under equalized conditions. According to Scanada Consultants (1983), this is approaching the range where mechanical ventilation systems would have to be considered.

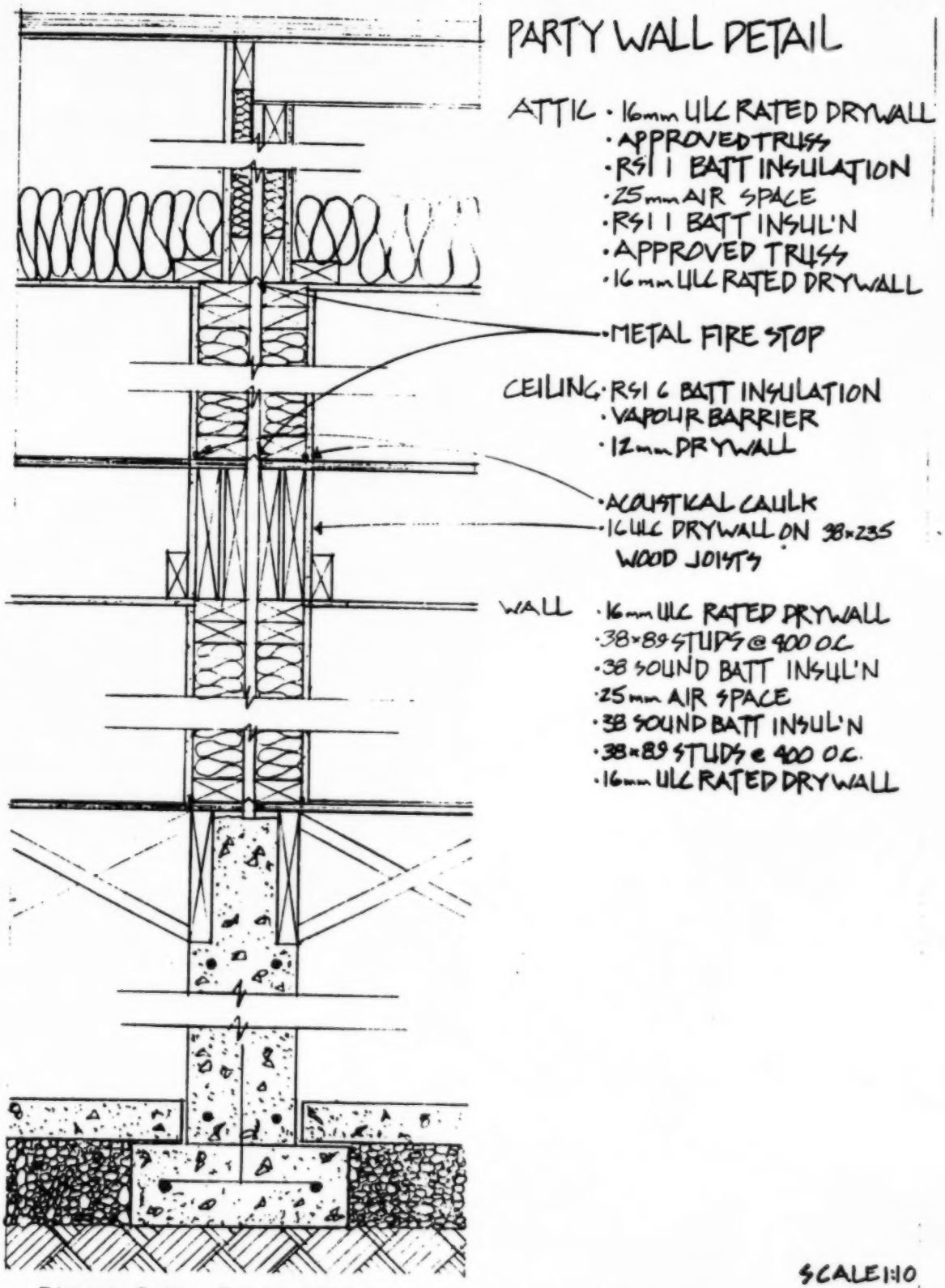

PARTY WALL DETAIL
ATTIC
• 16mm ULC RATED DRYWALL
• APPROVED TRUSS
• RSI 1 BATT INSULATION
• 25mm AIR SPACE
• RSI 1 BATT INSUL'N
• APPROVED TRUSS
• 16mm ULC RATED DRYWALL
• METAL FIRE STOP
CEILING
• RSI 6 BATT INSULATION
• VAPOUR BARRIER
• 12mm DRYWALL
• ACOUSTICAL CAULK
• 16 ULC DRYWALL ON 38×235 WOOD JOISTS
WALL
• 16mm ULC RATED DRYWALL
• 38×89 STUDS @ 400 OC
• 38 SOUND BATT INSUL'N
• 25mm AIR SPACE
• 38 SOUND BATT INSUL'N
• 38×89 STUDS @ 400 OC.
• 16mm ULC RATED DRYWALL
SCALE 1:10

Figure C.4b. Party wall section for project 4.

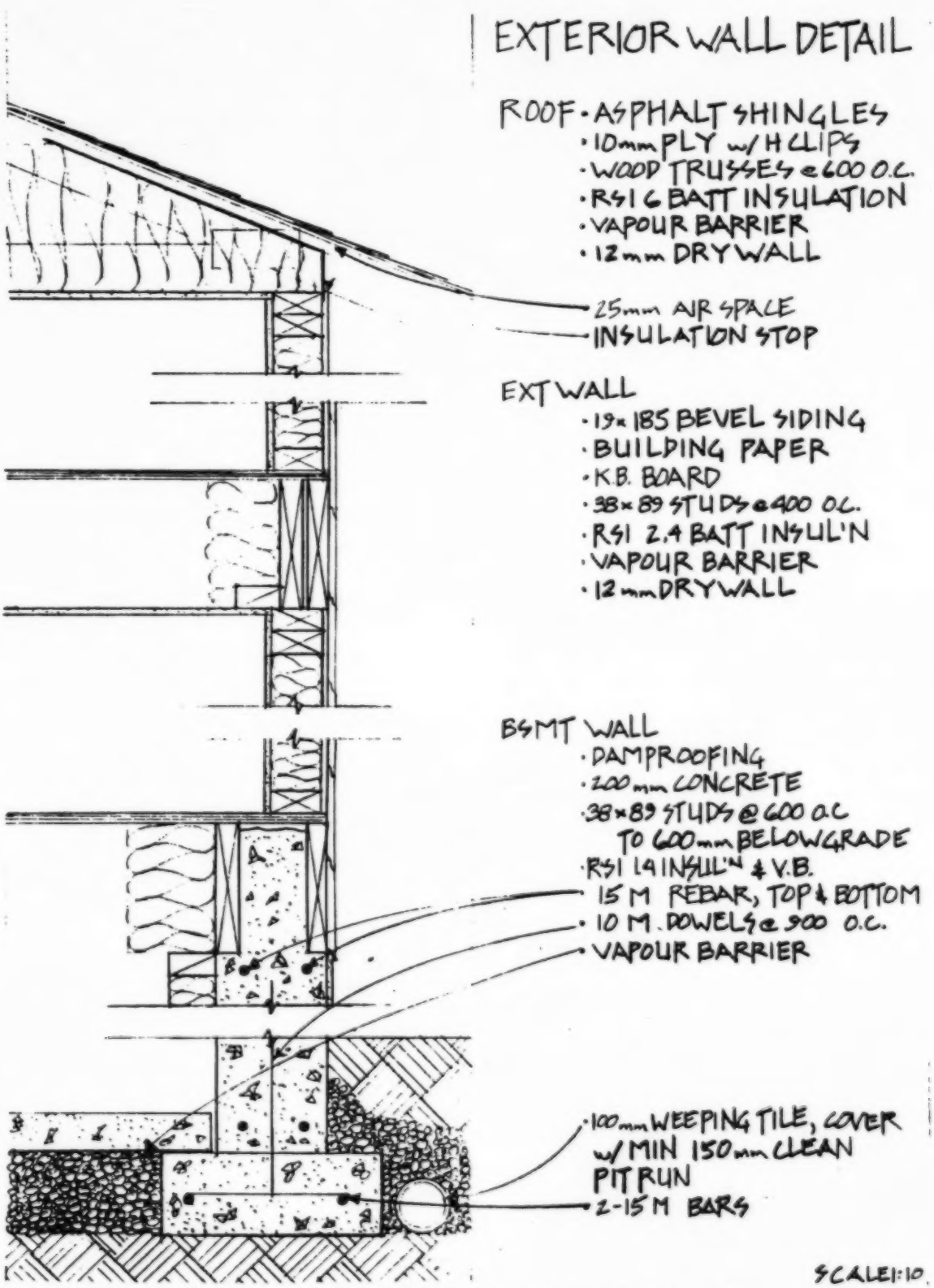

EXTERIOR WALL DETAIL
ROOF · ASPHALT SHINGLES
· 10mm PLY w/ H CLIPS
· WOOD TRUSSES @ 600 O.C.
· RSI 6 BATT INSULATION
· VAPOUR BARRIER
· 12mm DRYWALL
25mm AIR SPACE
INSULATION STOP
EXT WALL
· 19 x 185 BEVEL SIDING
· BUILDING PAPER
· K.B. BOARD
· 38 x 89 STUDS @ 400 O.C.
· RSI 2.4 BATT INSUL'N
· VAPOUR BARRIER
· 12mm DRYWALL
BSMT WALL
· DAMPROOFING
· 200mm CONCRETE
· 38 x 89 STUDS @ 600 O.C.
TO 600mm BELOW GRADE
· RSI 1.4 INSUL'N & V.B.
15 M REBAR, TOP & BOTTOM
· 10 M DOWELS @ 900 O.C.
· VAPOUR BARRIER
· 100mm WEEPING TILE, COVER
w/ MIN 150mm CLEAN
PIT RUN
2-15 M BARS
SCALE 1:10

Figure C.4c. Exterior wall section for project 4.

Project 5

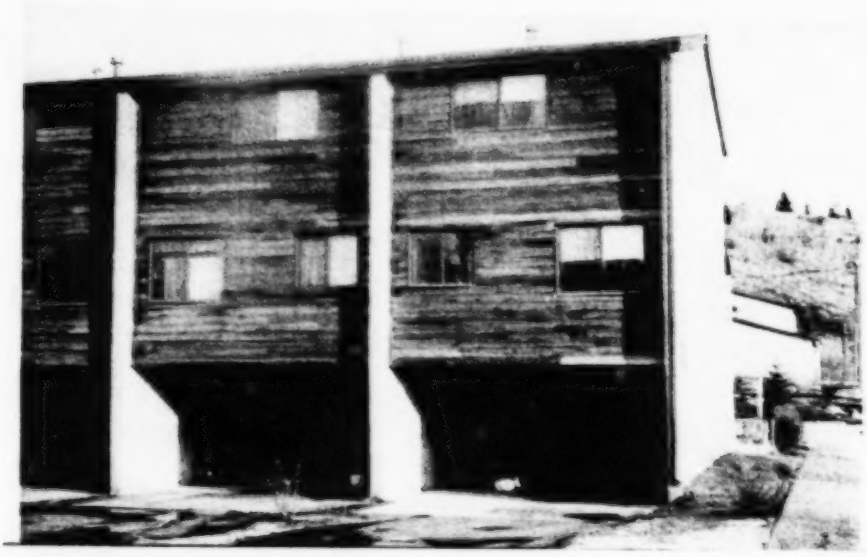


Figure C.5a. Photograph of a typical unit in Project 5.

Units in project 5 were found to be very leaky. Three units were tested under both unequalized and equalized conditions, resulting in average AC50's of 9.2 and 5.9 respectively (i.e. 36 percent of leakage through party wall). The equalized AC50 represents a very leaky shell, since the town houses are only exposed on two sides. Primary exterior leakage channels appear to be at the wall-ceiling junction and the sill plate/joist header area. This was the only project tested in which the joists ran from party wall to party wall (as opposed to the usual front to back arrangement). It may be that this is providing an additional air leakage path via the party wall, but the investigators were unable to test for this.

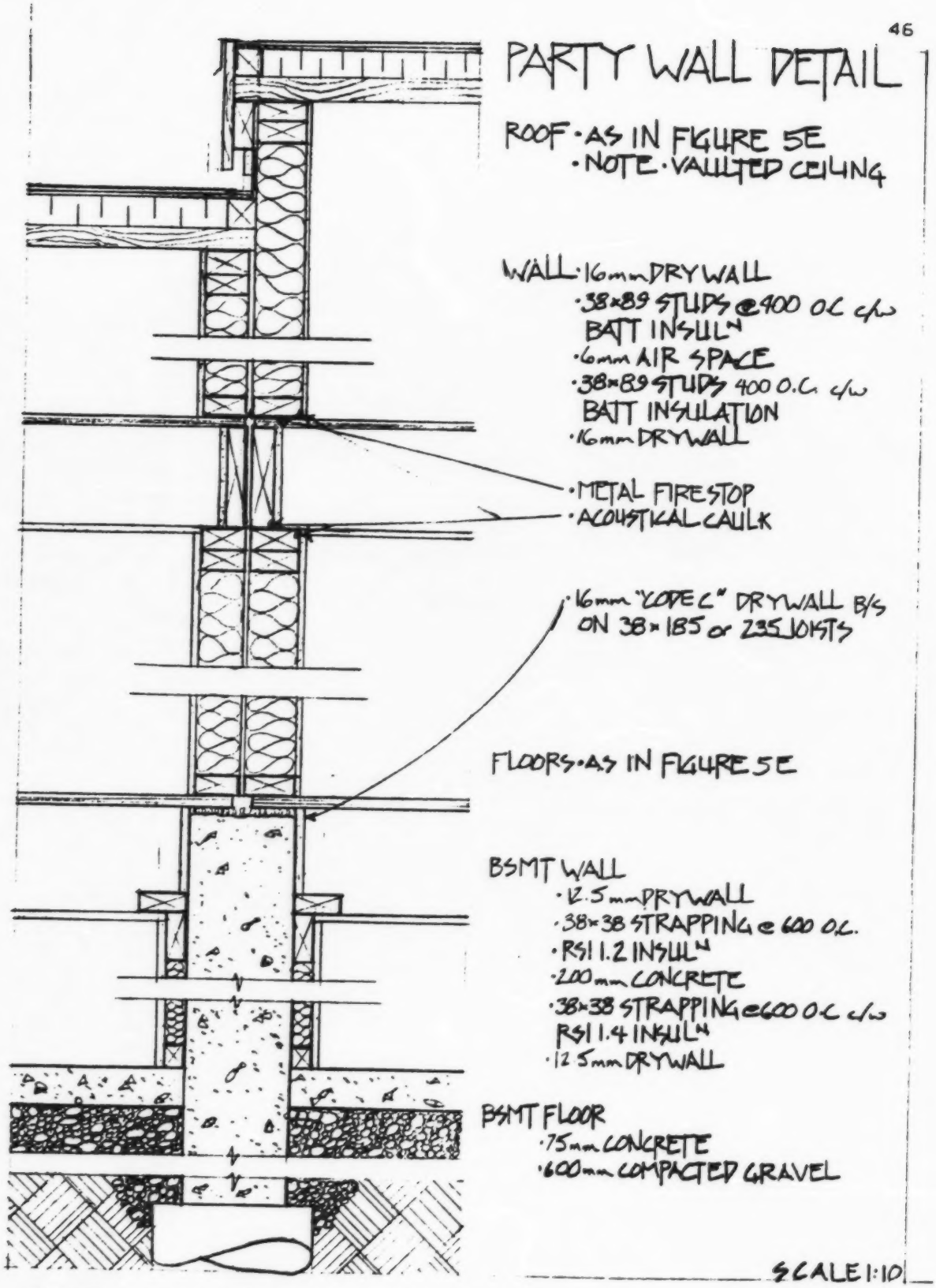

PARTY WALL DETAIL
ROOF · AS IN FIGURE 5E
· NOTE · VAULTED CEILING
WALL · 16mm DRYWALL
· 38×89 STUDS @ 400 O.C. c/w
BATT INSUL.N
· 6mm AIR SPACE
· 38×89 STUDS 400 O.C. c/w
BATT INSULATION
· 16mm DRYWALL
· METAL FIRESTOP
· ACOUSTICAL CAULK
· 16mm "TYPE C" DRYWALL B/S
ON 38×185 or 235 JOISTS
FLOORS · AS IN FIGURE 5E
BSMT WALL
· 12.5mm DRYWALL
· 38×38 STRAPPING @ 600 O.C.
· RSI 1.2 INSUL.N
· 200mm CONCRETE
· 38×38 STRAPPING @ 600 O.C. c/w
RSI 1.4 INSUL.N
· 12.5mm DRYWALL
BSMT FLOOR
· 75mm CONCRETE
· 600mm COMPACTED GRAVEL
SCALE 1:10

Figure C.5b. Party wall section for project 5.

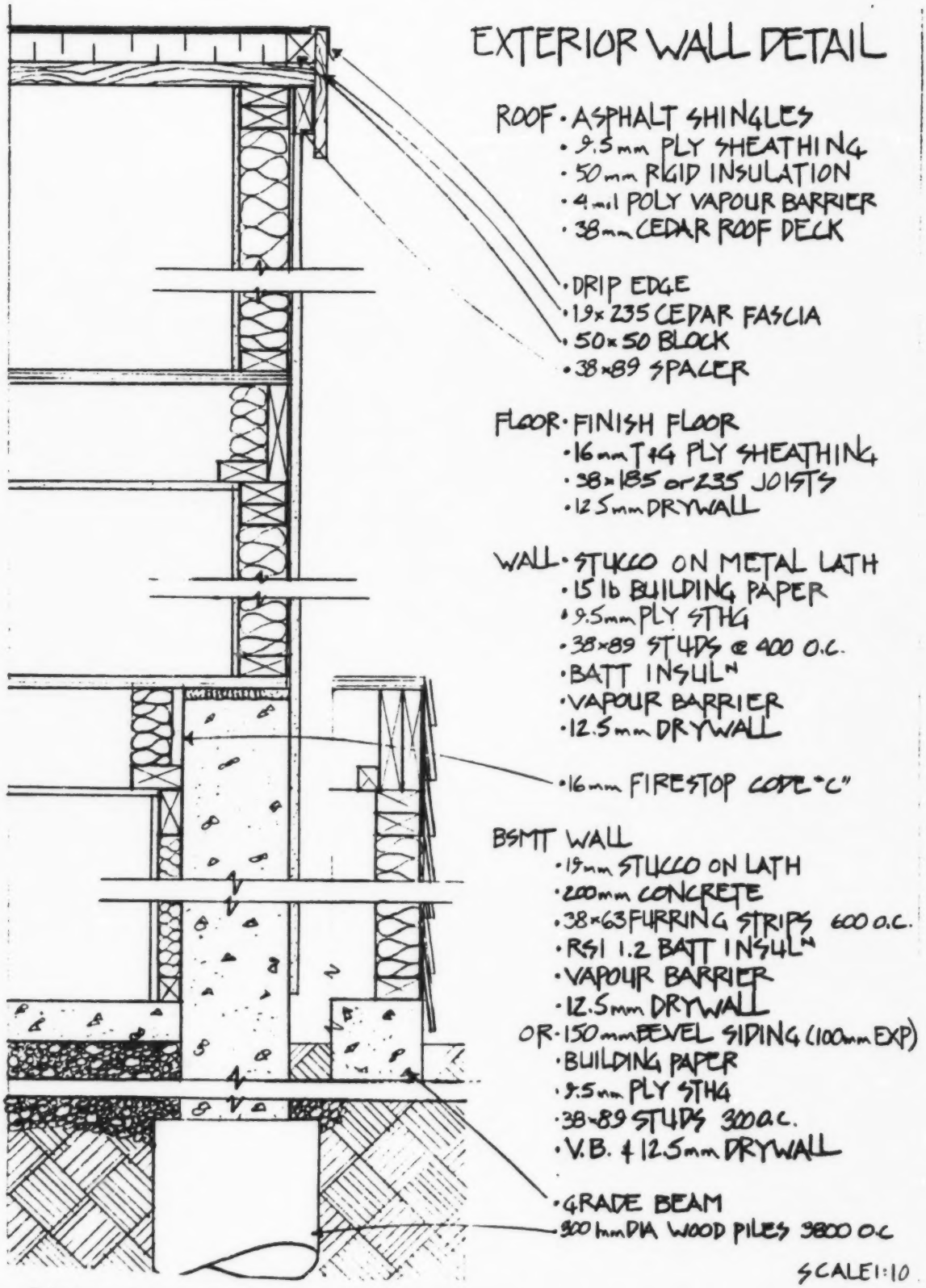

EXTERIOR WALL DETAIL
ROOF · ASPHALT SHINGLES
· 9.5mm PLY SHEATHING
· 50mm RIGID INSULATION
· 4 mil POLY VAPOUR BARRIER
· 38mm CEDAR ROOF DECK
· DRIP EDGE
· 19 x 235 CEDAR FASCIA
· 50 x 50 BLOCK
· 38 x 89 SPACER
FLOOR · FINISH FLOOR
· 16mm T&G PLY SHEATHING
· 38 x 185 or 235 JOISTS
· 12.5mm DRYWALL
WALL · STUCCO ON METAL LATH
· 15 lb BUILDING PAPER
· 9.5mm PLY STHG
· 38 x 89 STUDS @ 400 O.C.
· BATT INSUL'N
· VAPOUR BARRIER
· 12.5mm DRYWALL
· 16mm FIRESTOP CODE "C"
BSMT WALL
· 19mm STUCCO ON LATH
· 200mm CONCRETE
· 38 x 63 FURRING STRIPS 600 O.C.
· RSI 1.2 BATT INSUL'N
· VAPOUR BARRIER
· 12.5mm DRYWALL
OR · 150mm BEVEL SIDING (100mm EXP)
· BUILDING PAPER
· 9.5mm PLY STHG
· 38-89 STUDS 300 O.C.
· V.B. & 12.5mm DRYWALL
· GRADE BEAM
· 300mm DIA WOOD PILES 3800 O.C
SCALE 1:10

Figure C.5c. Exterior wall section for project 5.

Project 6

Figure C.6a. Photograph of a typical unit in Project 6.

Two units from the project were tested under equalized conditions; the average AC50 was found to be 3.0 which is double the 1.5 maximum required under the R2000 program. According to Scanada Consultants (1983), this is approaching the range where mechanical ventilation systems would have to be considered.

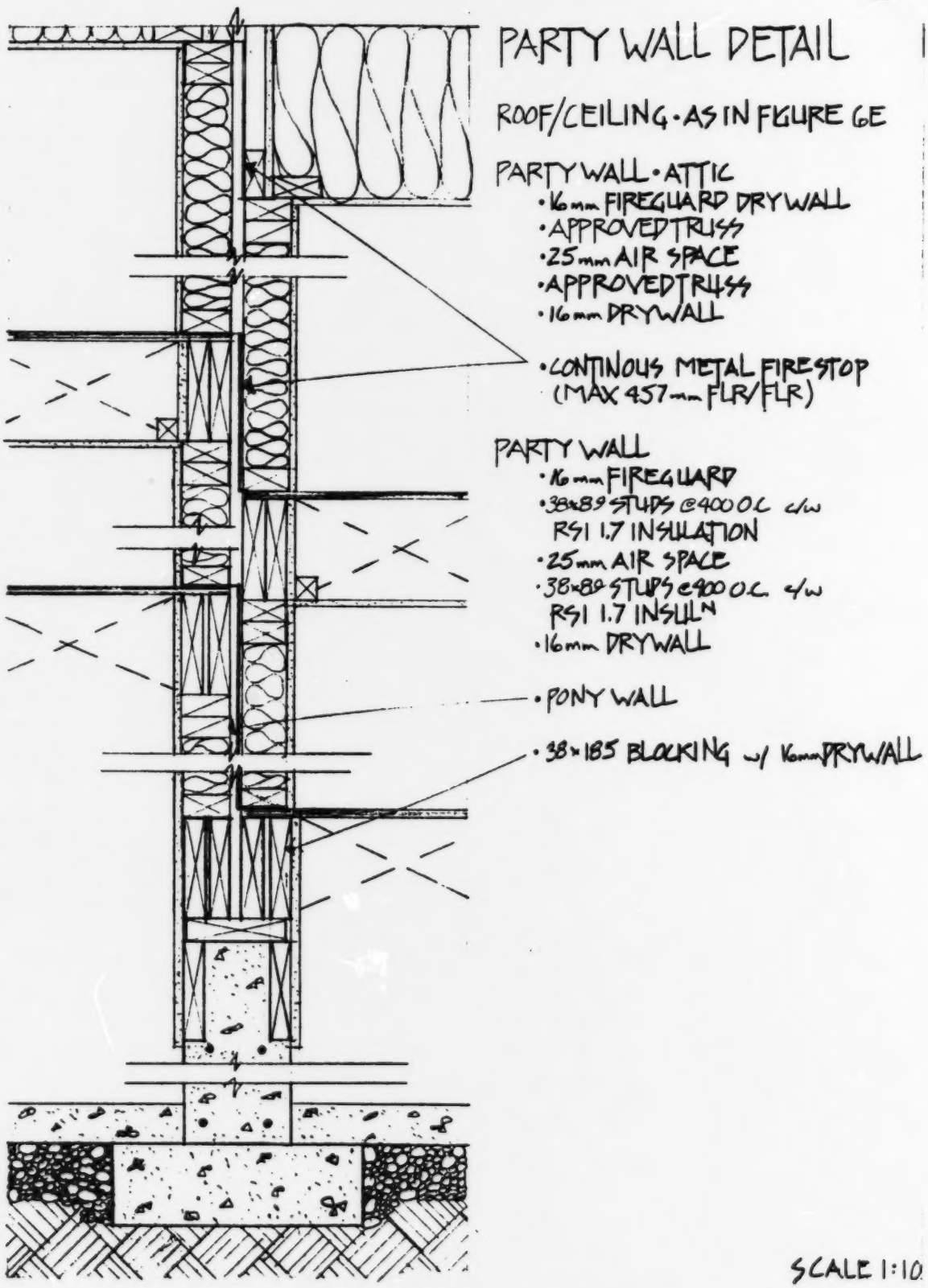

PARTY WALL DETAIL
ROOF/CEILING - AS IN FIGURE 6E
PARTY WALL - ATTIC
• 16mm FIREGUARD DRYWALL
• APPROVED TRUSS
• 25mm AIR SPACE
• APPROVED TRUSS
• 16mm DRYWALL
• CONTINOUS METAL FIRESTOP (MAX 457mm FLR/FLR)
PARTY WALL
• 16mm FIREGUARD
• 38x89 STUDS @400 O.C. c/w RSI 1.7 INSULATION
• 25mm AIR SPACE
• 38x89 STUDS @400 O.C. c/w RSI 1.7 INSUL'N
• 16mm DRYWALL
• PONY WALL
• 38x185 BLOCKING w/ 16mm DRYWALL
SCALE 1:10

Figure C.6b. Party wall section for project 6.

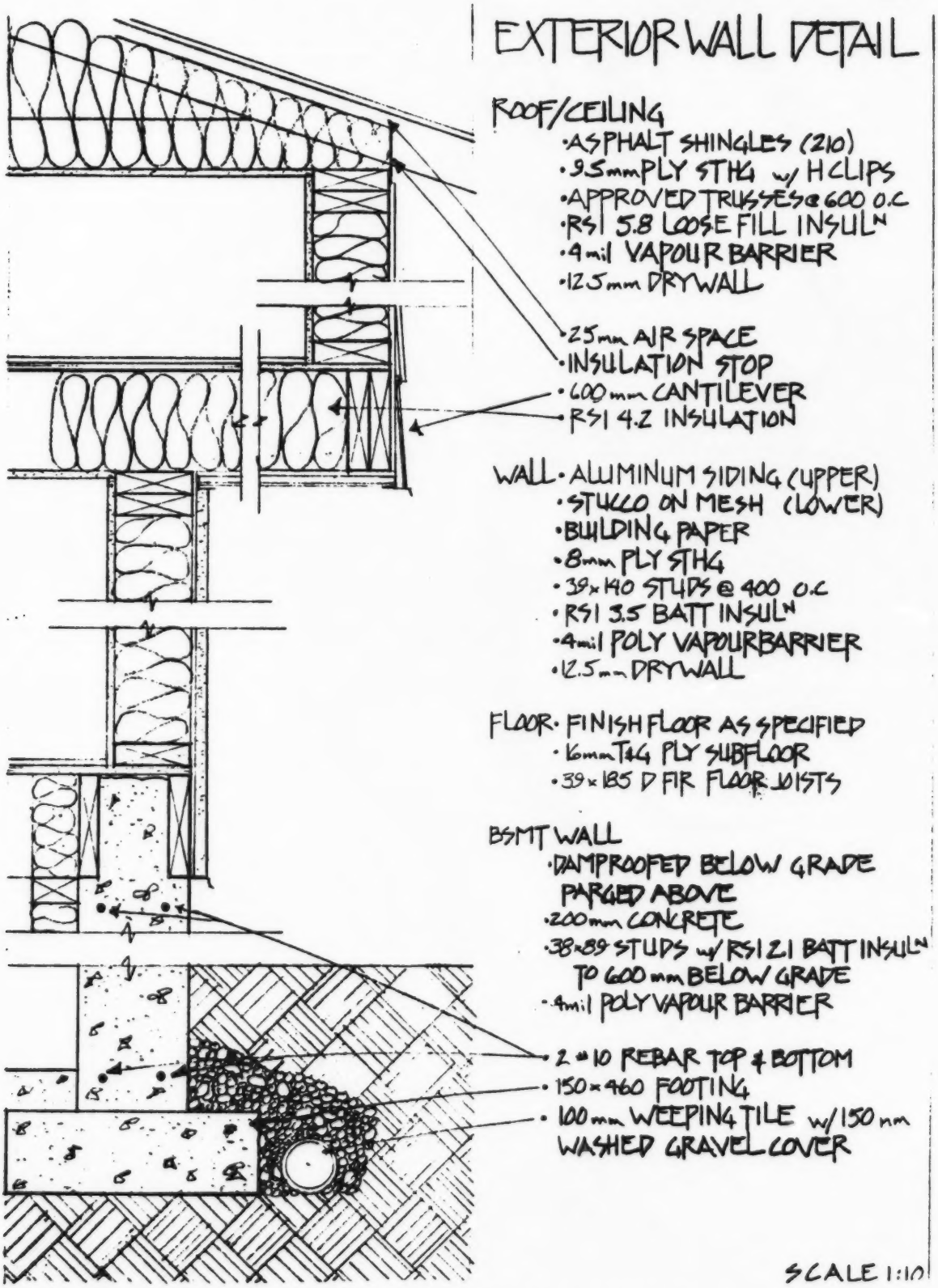


Figure C.6c. Exterior wall section for project 6.

Project 7

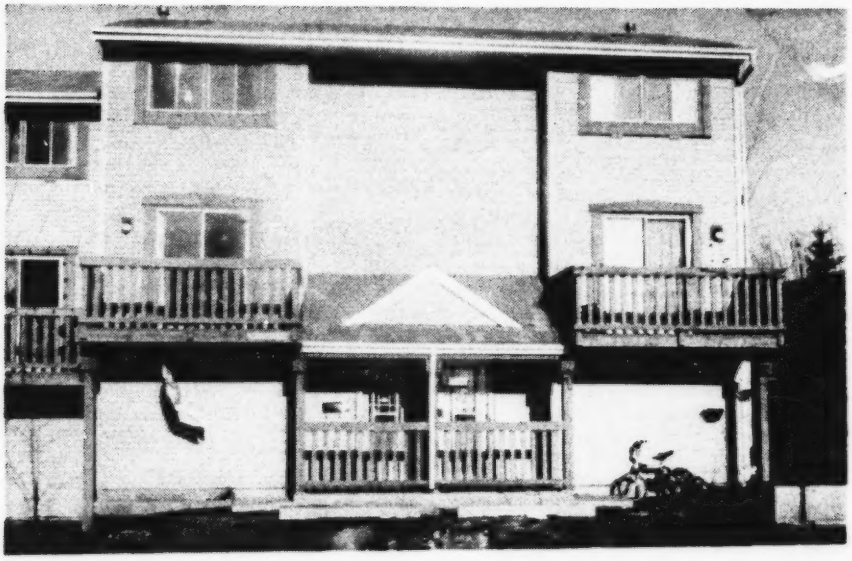


Figure C.7a. Photograph of a typical unit in Project 7.

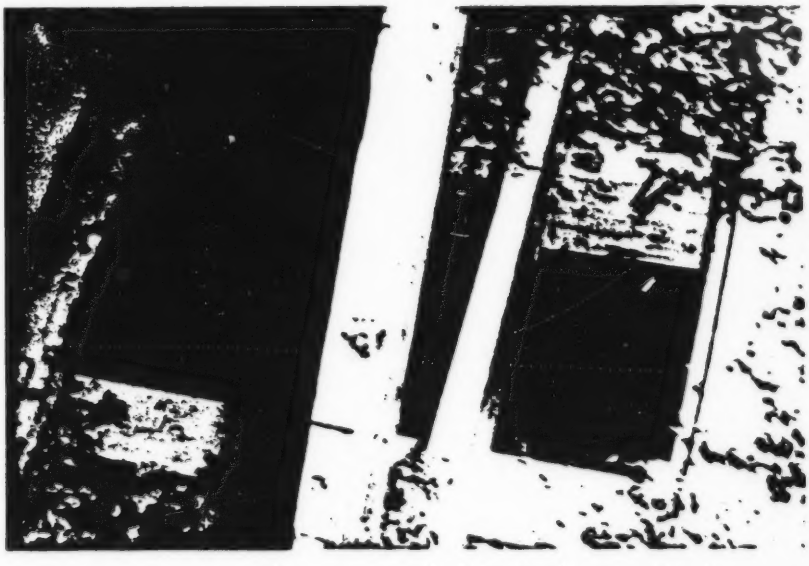


Figure C.7b. Photograph of Ø.6 m by Ø.3 m hole in ceiling of unit 7-2.

Five units from project 7 were tested under equalized conditions, and had an average AC5Ø of 3.5. According to Scanada Consultants (1983), this is approaching the range where mechanical

ventilation systems would have to be considered. Two units registered 2.2 and 2.5 - only about 50% higher than the maximum allowed for R2000 houses; the occupants had undertaken extensive air sealing.

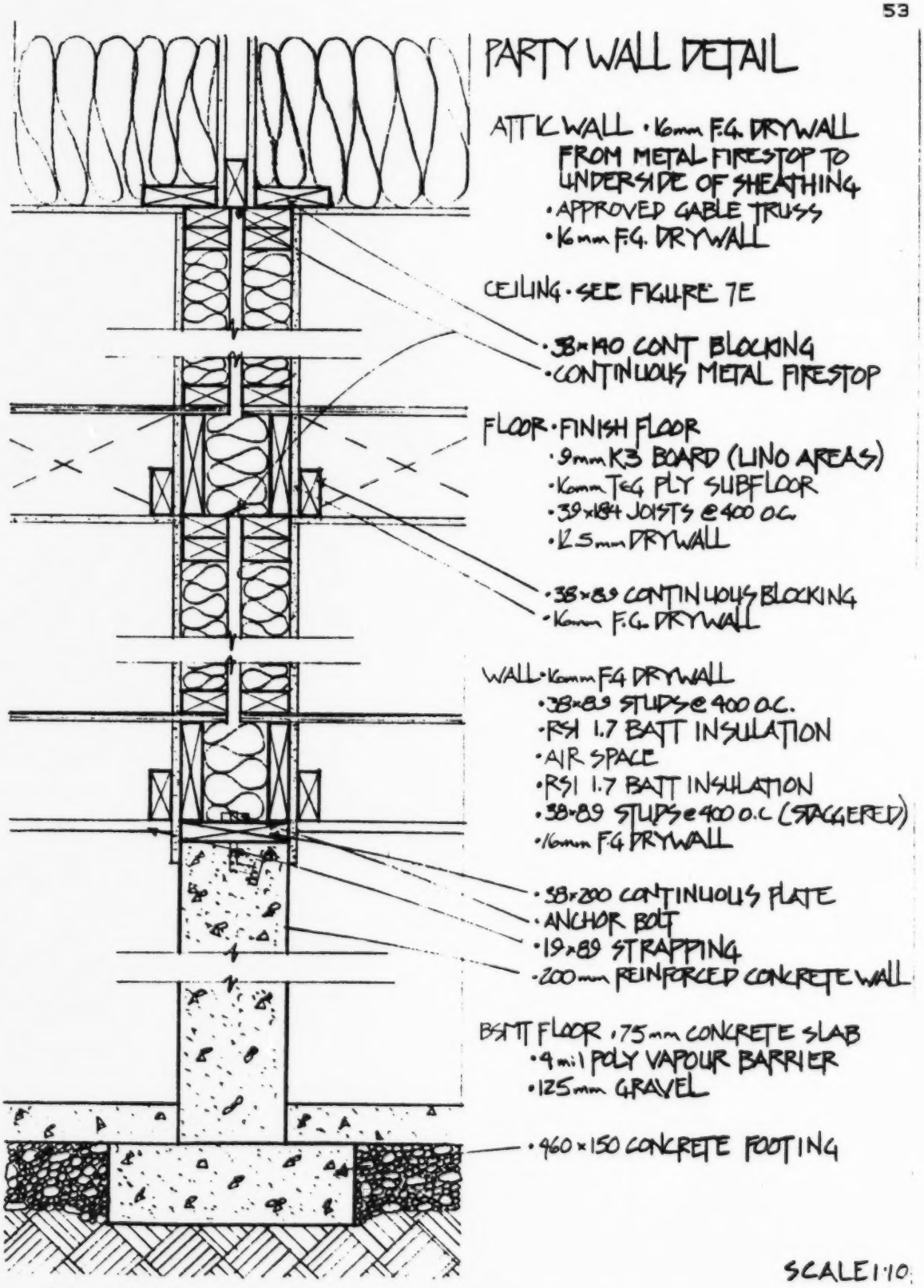
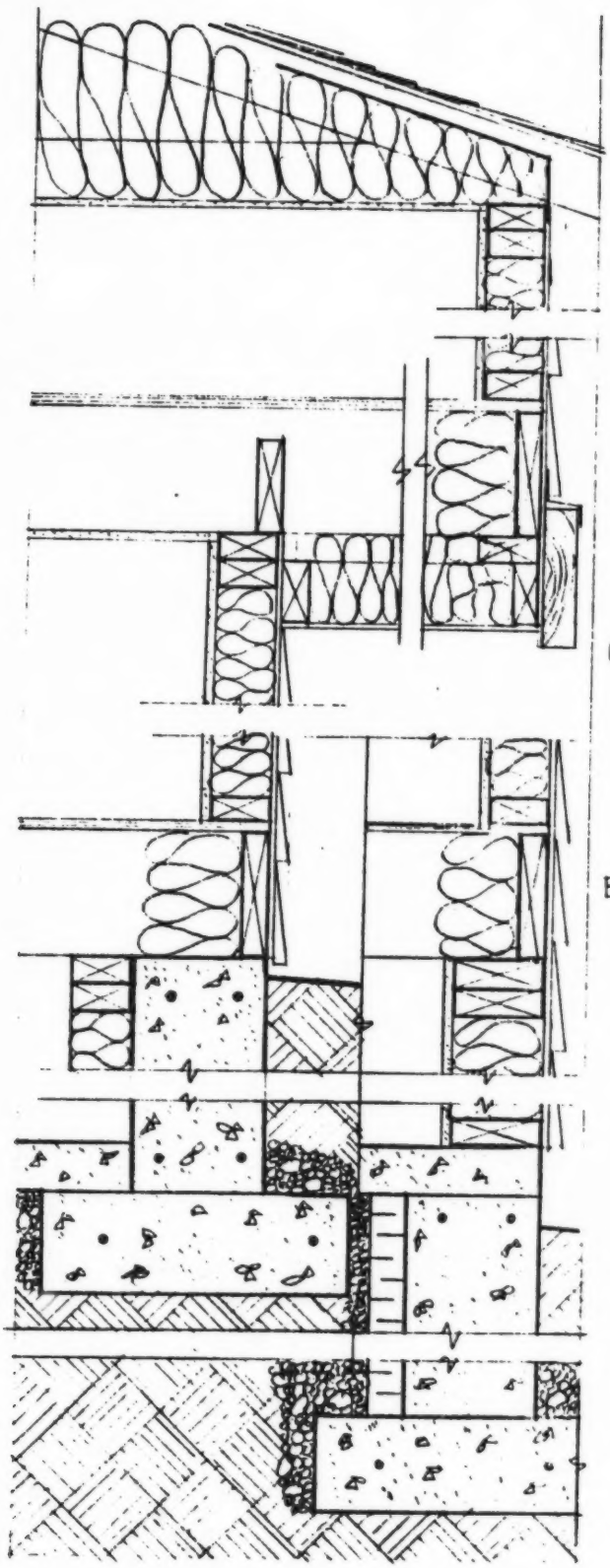

PARTY WALL DETAIL
ATTIC WALL • 16mm F.G. DRYWALL
FROM METAL FIRESTOP TO
UNDERSIDE OF SHEATHING
• APPROVED GABLE TRUSS
• 16mm F.G. DRYWALL
CEILING • SEE FIGURE 7E
• 38×140 CONT BLOCKING
• CONTINUOUS METAL FIRESTOP
FLOOR • FINISH FLOOR
• 9mm K3 BOARD (LINO AREAS)
• 6mm T&G PLY SUBFLOOR
• 39×184 JOISTS @ 400 O.C.
• 12.5mm DRYWALL
• 38×89 CONTINUOUS BLOCKING
• 16mm F.G. DRYWALL
WALL • 16mm FG DRYWALL
• 38×89 STUDS @ 400 O.C.
• RSI 1.7 BATT INSULATION
• AIR SPACE
• RSI 1.7 BATT INSULATION
• 38×89 STUDS @ 400 O.C (STAGGERED)
• 16mm FG DRYWALL
• 38×200 CONTINUOUS PLATE
• ANCHOR BOLT
• 19×89 STRAPPING
• 200mm REINFORCED CONCRETE WALL
BSMT FLOOR • 75mm CONCRETE SLAB
• 4 mil POLY VAPOUR BARRIER
• 125mm GRAVEL
• 460×150 CONCRETE FOOTING
SCALE 1:10

Figure C.7c. Party wall section for project 7.



EXTERIOR WALL DETAIL

ROOF • ASPHALT SHINGLES
- 9mm PLY SHTG w/ H-CLIPS
- TRUSSES 600 O.C.
- RSI 5.6 BATT INSUL^N or EQUAL
- 4 mil POLY VAPOUR BARRIER
- 12.5mm DRYWALL

WALL • ALUMINUM SIDING
- BUILDING PAPER
- 7mm PLY SHEATHING
- 38×89 STUDS @ 400 O.C.
- RSI 2.1 BATT INSULATION
- 4 mil POLY VAPOUR BARRIER
- 12.5 mm DRYWALL

CANTILEVER • (600, ONE SIDE)
- 16mm T&G PLY SUBFLOOR
- 38×185 JOISTS 400 O.C.
- 4 mil POLY VAPOUR BARRIER
- RSI 3.5 BATT INSUL^N
- 38×89 FRAMING ALUM^N SOFFIT

BSMT WALL (BELOW GRADE)
- DAMPROOFED
- 200 mm REINFORCED CONCRETE
- 38×89 STUDS 600 O.C. TO 600 BELOW
- RSI 1.4 INSUL^N, VAPOUR BARRIER

(OPEN TO GRADE)
- ALUMINUM SIDING
- BUILDING PAPER
- 7mm PLY SHTG
- 38×140 BEARING WALL
- RSI 2.1 BATT INSUL^N
- 4 mil POLY VAPOUR BARRIER
- 12.5 mm DRYWALL

- 200mm REINFORCED CONCRETE FROST WALL, 50mm RIGID INSUL^N
- 460×150 CONCRETE FOOTING

SCALE 1:10

Figure C.7d. Exterior wall section for project 7.

Project 8

Figure C.8a. Photograph of a typical unit in Project 8.

Units in project 8 were found to be very leaky. Two end units were tested under unequalized conditions, and had an average AC5Ø of 1Ø.2. This represents an equalized value of approximately 7.5. On this one project, it was possible to obtain information from infrared scans. It was found that there were many gaps in the vapour barrier (while it would not affect air leakage, it was also noted that batts of insulation were missing from stud wall cavities - an indication of extremely poor workmanship). Substantial air leaks were found where the fireplace chimney penetrated through the wall of the dwelling, and around plumbing stacks and the furnace flue in the attic.

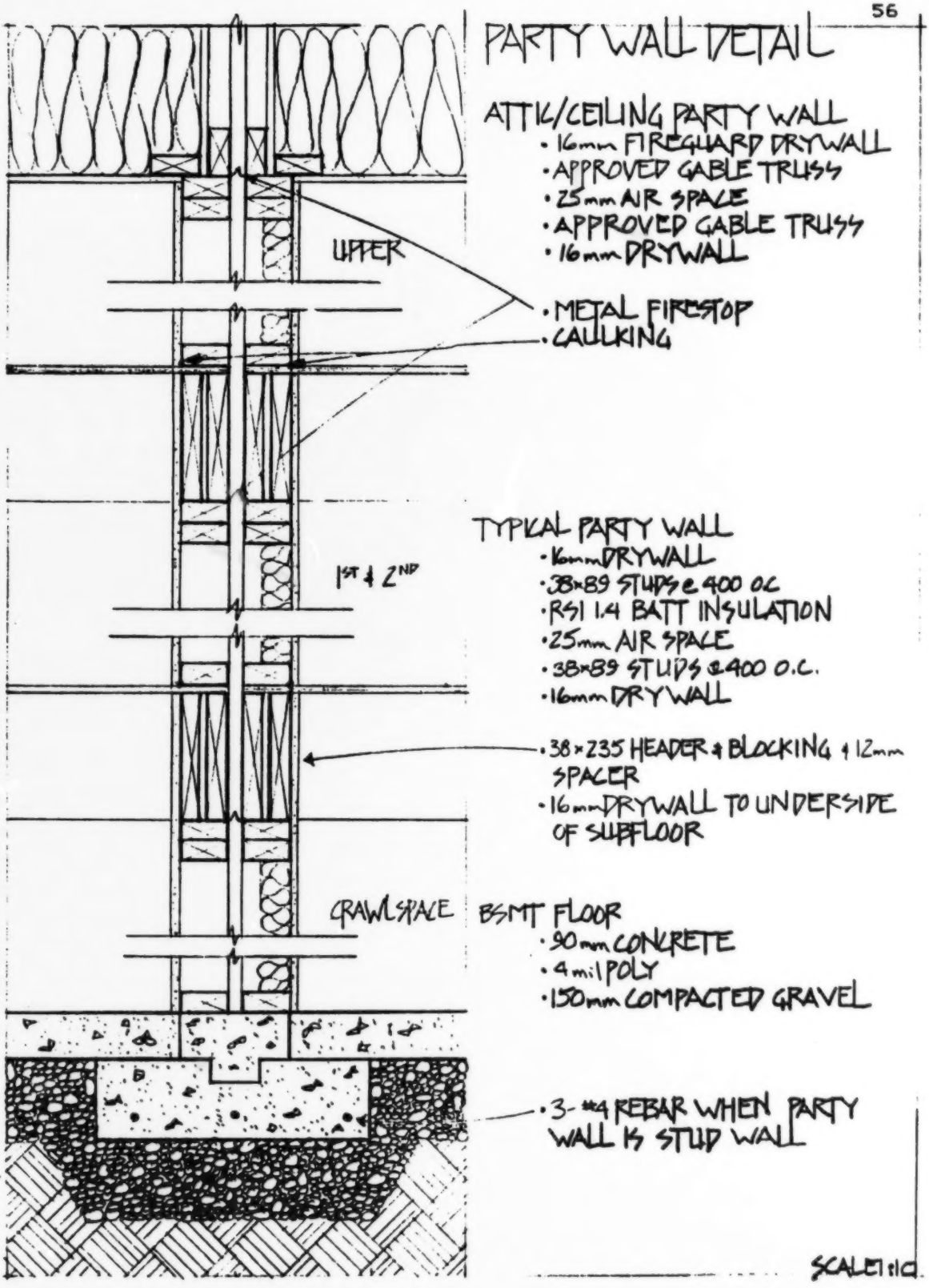


Figure C.8b. Party wall section for project B.

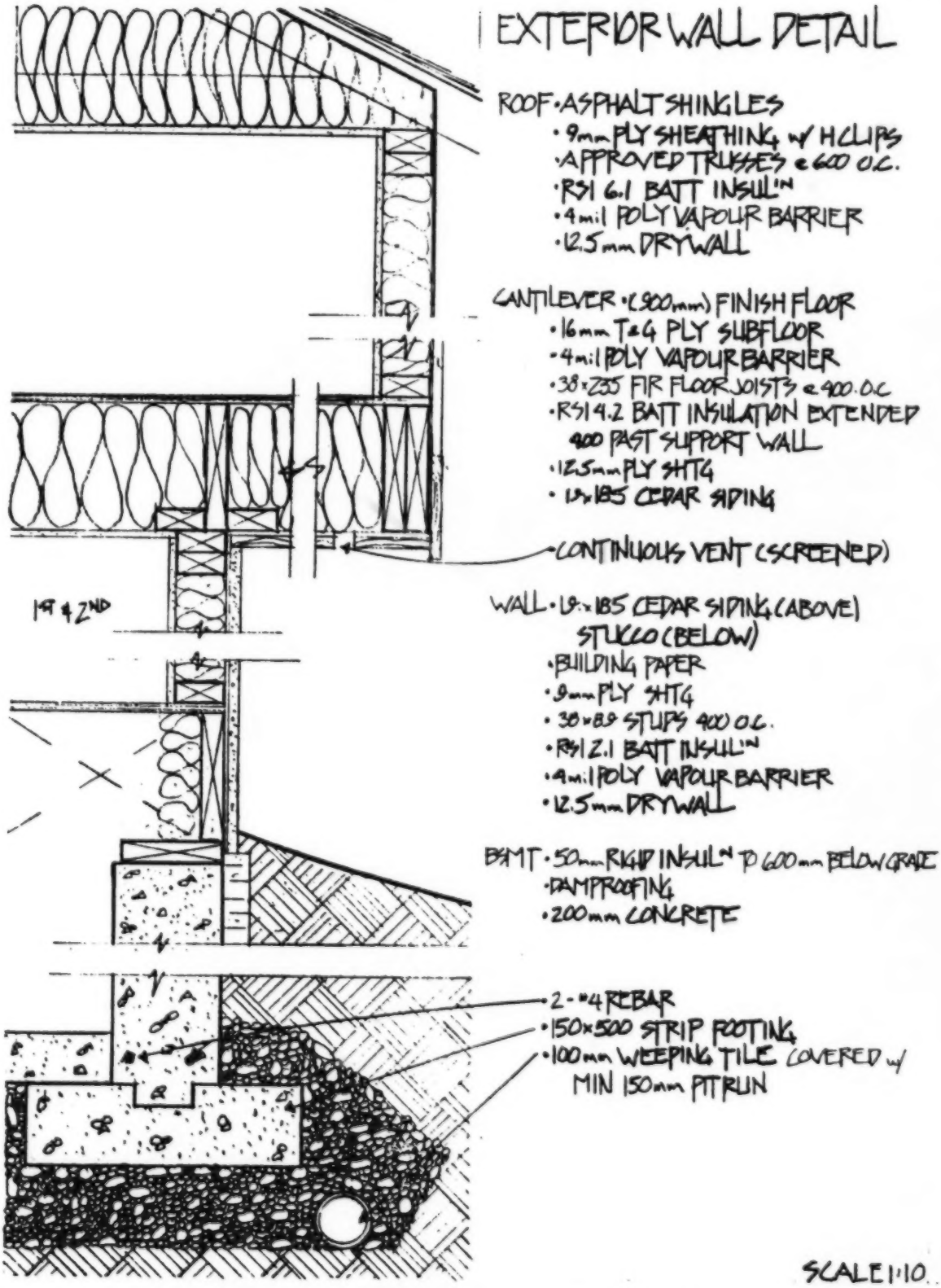

EXTERIOR WALL DETAIL
ROOF • ASPHALT SHINGLES
• 9mm PLY SHEATHING w/ H CLIPS
• APPROVED TRUSSES @ 600 O.C.
• RSI 6.1 BATT INSUL'N
• 4 mil POLY VAPOUR BARRIER
• 12.5 mm DRYWALL
CANTILEVER • (900mm) FINISH FLOOR
• 16mm T&G PLY SUBFLOOR
• 4 mil POLY VAPOUR BARRIER
• 38 x 235 FIR FLOOR JOISTS @ 400 O.C
• RSI 4.2 BATT INSULATION EXTENDED 400 PAST SUPPORT WALL
• 12.5mm PLY SHTG
• 13 x 185 CEDAR SIDING
CONTINUOUS VENT (SCREENED)
1ST & 2ND
WALL • 13 x 185 CEDAR SIDING (ABOVE)
STUCCO (BELOW)
• BUILDING PAPER
• 9mm PLY SHTG
• 38 x 89 STUDS 400 O.C.
• RSI 2.1 BATT INSUL'N
• 4 mil POLY VAPOUR BARRIER
• 12.5mm DRYWALL
BSMT • 50mm RIGID INSUL'N TO 600mm BELOW GRADE
• DAMPROOFING
• 200mm CONCRETE
2 - #4 REBAR
• 150 x 500 STRIP FOOTING
• 100mm WEEPING TILE COVERED w/ MIN 150mm PIT RUN
SCALE 1:10

Figure C.8c. Exterior wall section for project B.